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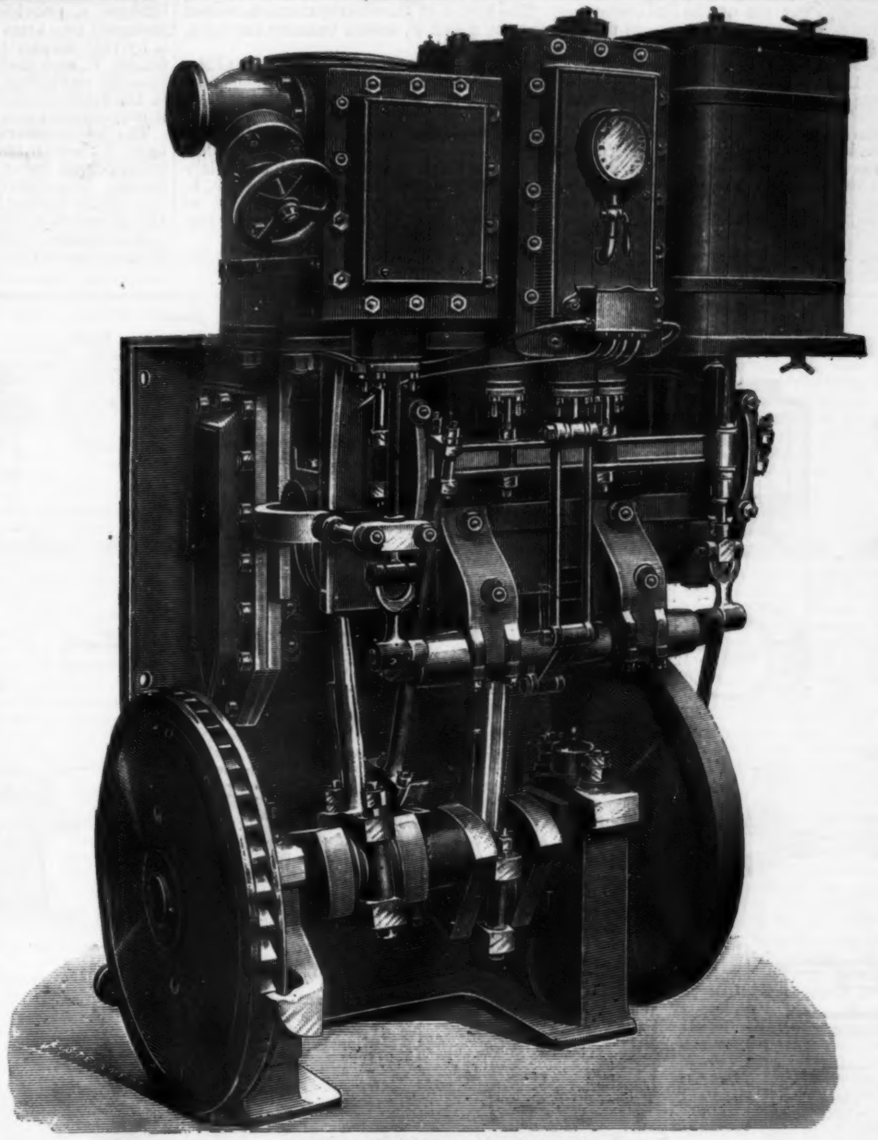
COLD STORAGE ON SHIPBOARD.

On board ship lunch and dinner are to the passenger the chief events of the day, to be looked forward to during the tedious hours which are so difficult to fill, as brief intervals during which the attention is fully and pleasantly engaged. Probably this was always the case, even in the East Indiaman, which often occupied six months in her voyage. But how different were the meals then served from those which appear in the saloons of the great lines of steamers now running to India and Australia! The fresh provisions had all to be carried alive, and during the short time they spent on the decks the animals deteriorated woefully. The fowls became as spare as greyhounds, and apparently quite as muscular, while the bullocks and the sheep lost flesh and flavor until they would bear comparison with nothing but salt junk. The water and the wine grew lukewarm in the tropics, and there was neither fresh fruit nor vegetables to vary the fare. Now, after the seasickness is over, a passenger eats more and enjoys it better than ever he does on land. The fresh air gives him a splendid appetite, and at every meal he finds a bill of fare corresponding to that of a first-class hotel on shore, while the viands and the cooking are both of the best. This change is due to the introduction of cold storage on board ship. The meat, milk, fruit, and vegetables are defended from decay by being kept in a room at a freezing temperature, and are used as required. Often thousands of carcasses are carried in the hold to be consumed in England after having lived and been killed in Australia and New Zealand. The method of storage and refrigeration is shown in the lower engraving. The carcasses are cooled on shore to a temperature of 45° to 50° Fahr. below freezing, and brought on board perfectly hard and rigid. They are stacked in rows in a chamber formed in the hold, and inclosed within double walls filled with ground charcoal. Along the center of the chamber there runs a perforated trunk through which the cold air from the refrigerating machine is emitted. The air sinks through the rows of carcasses, which rest on battens or gratings, not shown in the engraving, and is afterward drawn out through trunks placed against the sides of the chamber, to the refrigerating machine, which in the illustration is one by Messrs. J. & E. Hall, of Dartford. There is a large trade of this kind carried on between Barracas, in the Argentine Republic, and France, and it is found that after paying a duty of £4 7s. 6d. a ton on the meat and a city octroi of £4 18s. 4d. a ton, the shippers can make a profit of £3 3s. 6d. a ton.

The provisions carried for the ship's use are stored in a chamber between decks. There are wine cooling racks, A, a water cooler, B, ice pails, C, besides hooks and racks for other viands. Where a ship is not designed to carry carcasses for consumption in Europe, and has only to supply her own needs, a much smaller refrigerating machine suffices.



REFRIGERATING MACHINE.

The machines usually made for this purpose have been designed to work horizontally, and owing to the space which they occupied, it has been necessary to place them away from the engine room in the hold or 'tween decks, thus reducing the space available for cargo and requiring special attendance. The machine illustrated is usually bolted up against the after bulkhead in the main engine room, and thus comes under the care of the engineer on watch, who can run it as the temperature of the cold chamber requires, a thermometer to show this being within his reach.

As much as 8 to 10 tons of meat, vegetables, etc., including all the milk, butter, and other perishable stores, can be preserved with this little machine without throwing any appreciable additional working expenses on the ship and with very little attention from the engineer on duty. The principles on which these cold air machines are based have been so often described that it will be sufficient to mention that the cold is produced merely by the compression and expansion of atmospheric air, without the use of any chemical material.—*Engineering.*

COLD STORAGE ON SHIPBOARD.

NIGHT NAVIGATION ON THE SUEZ CANAL.

An interesting paper has been read by M. P. Lemonnier before the International Society of Electricians, at Paris, in which he gave some particulars regarding the use of electric search lights on vessels passing through the Suez Canal by night. It appears that since March, 1887, when night traffic was first permitted, some eight hundred vessels have passed through the canal by the aid of the electric light. Of these, slightly over three hundred carried their own lighting plant, the rest of the vessels having obtained the plant from one of the two companies who make it a business to supply the necessary apparatus on hire.

These firms are the Societe Bazin & Cie., whose plant is of English make, and the Societe Worms, Josse & Cie., whose plant is of French make, being manufactured by Messrs. Sautter - Lemonnier & Cie. These firms have depots at either end of the canal, and upon a vessel arriving the plant is hoisted on board, installed by the firms' servants, and superintended by them throughout the passage.

On arriving at the other end of the canal the plant is put on shore, and held in readiness for the next vessel passing in the opposite direction. To avoid delays, it is advantageous

that captains should telegraph beforehand either to Suez or Port Said, and to either of the firms mentioned, stating at what hour they will require the electric plant. The latter consists of a steam dynamo weighing about 1 ton 18 cwt., the necessary cable, and a wooden cabin containing the search light, which is hung over the bow of the steamer. The cabin may be suspended from the bowsprit, or, where the vessel is unprovided with a bowsprit, a spar with a pulley at its end must be run out over the bow. Steam must be supplied from either of the main boilers or from a donkey boiler on the vessel, the minimum pressure required being 60 lb. The cost of hire for a single passage is $50.

APPARATUS FOR THE EXTRACTION OF WATER OF CONDENSATION.

IN the numerous apparatus heated by steam used in various industries, it is indispensable to get rid of the water of condensation, and for this purpose many devices have been proposed. These may be divided into three categories: those which act through a float, those which act by gravity, and those which act through expansion. Of these we shall describe the principal types.

Float Extractors.—There are two systems of float extractors. In the first, the float is a hermetically closed hollow sphere which, inclosed in a reservoir in communication with the conduit to be emptied, has no other mission than to open an eduction valve when the water of condensation has reached a certain level in the reservoir.

In the second, the float is open, so that it can fill other the counterpoise, *p*, designed to balance the double valve, *s*, and cause it to work regularly. At one extremity there is a key, A, designed to make the lever, L, oscillate, and consequently to cause the valve to operate if it gets wedged in its double seat.

The Legat extractor, shown in section and plan in Fig. 5, affords a type of the second system. It consists of a box, R, hermetically closed by a cover, C, provided with an air cock, *r*. It is cast in a piece with tubulures, T and T', through which the water of condensation enters and escapes. The tubulure, T', communicates through a channel, *t*, with the shell of a cock whose plug is hollow and contains two apertures, one of them communicating with the channel and the other with the hollow lever, L, which debouches at the bottom of the hollow float. The entrance and exit orifices are provided with a double isolating cock, M, which permits of passing the water directly into the eduction pipe in order to inspect the apparatus without stopping its operation. The key, *c*, of the distributor is mounted upon pointed screws, *v* and *v'*, which balance the cock, lever, and float.

Fig. 6 represents the extractor of Messrs. Lethuillier & Pinel. It consists of a rectangular cast iron box, R, cast in a piece with the eduction tubulure, T', and closed by a cover, C.

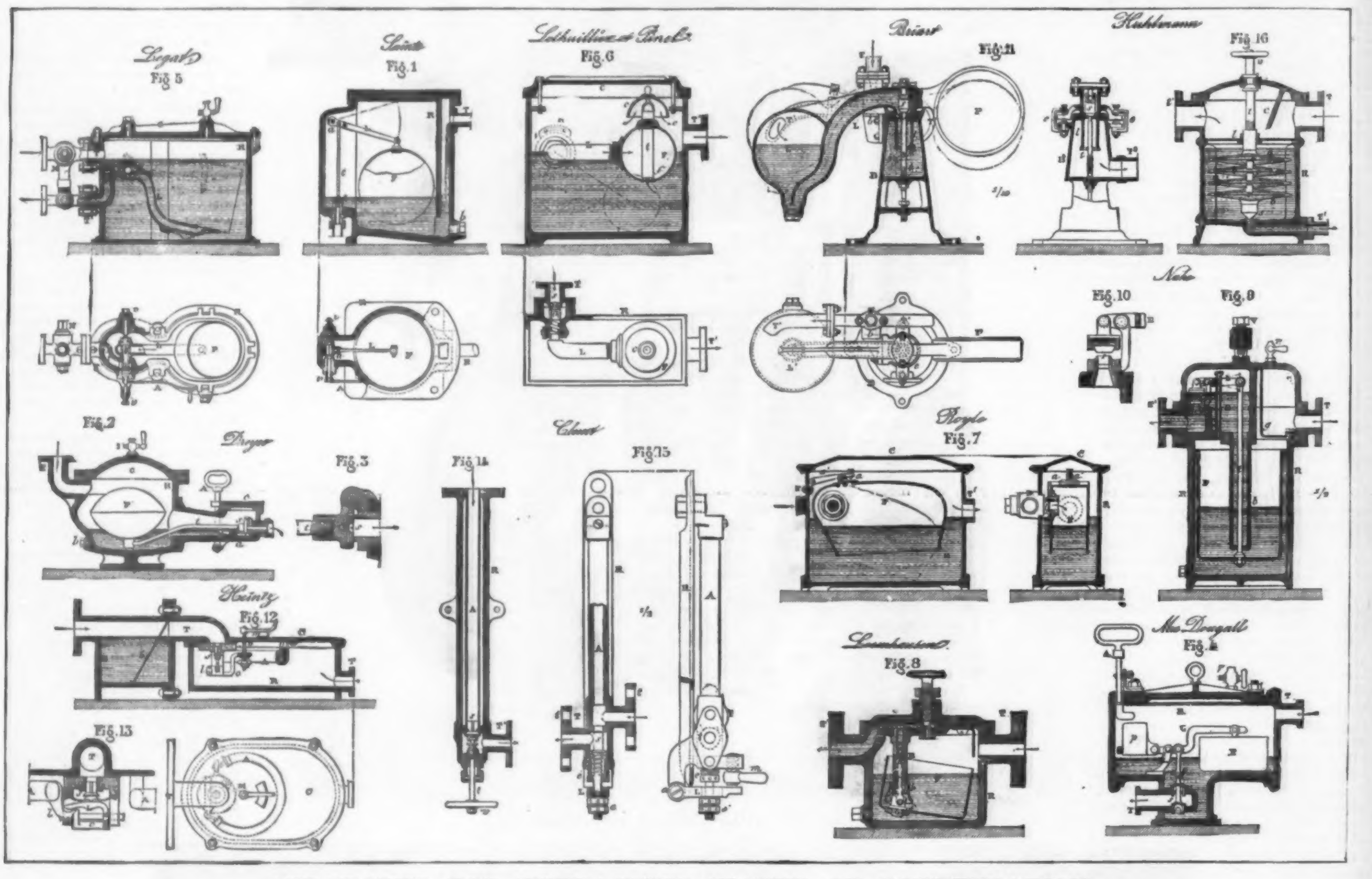
The opening and closing of the entrance orifice, T, are regulated by a valve, *s*, set into the head of a hollow bronze screw, *v*. This latter turns freely in a stationary bronze nut which is connected by a bent tube, L, with a copper float, F, that has an aperture, *f*, at the bottom, opposite the plunge tube, *t*, which is surmounted by a bell, *c*.

The reservoir is first filled with water up to the tu- valve, *s*, takes place through the intermedium of a long rod, *t*, and a jointed lever, L—an arrangement that furnishes a greater and prompter stress than is obtained in those apparatus in which the float acts by its weight only. As shown in Fig. 10, the valve, *s*, is suspended freely in a box that permits it to center itself automatically in order to apply itself to its seat and make a tight joint. The water escapes through the tubulure, T, with the constant counterpressure of ¼ atmosphere.

Gravity Extractors.—Mr. Briart's extractor is shown in plan and section in Fig. 11. Its operation is based upon the alternate oscillation of the lever, L, which carries at one side the hollow sphere, L', that receives the water of condensation, and at the other the counterpoise, P, that balances the sphere when the latter is three quarters full of water. To this effect, the lever is cast hollow with a central tubulure, *l*, which penetrates as far as to the center of the frame, B, which is cast in a piece with two flanges that receive bridges, *e*, provided with points between which are mounted two arms forming part of the tubulure, *l*. It is by this means that the lever is supported by the frame, B, and that it can oscillate freely, its motion opening or closing the valve, *s*, whose rod, *t*, is placed in the center of the frame, and is jointed in order that it may adapt itself to the tilting motion of the lever.

The water enters the sphere, L, through the copper tube, T', which starts from the tube, T, whose flange is supported by an arm, *b*, cast in a piece with the frame. The water makes its exit through a prolongation of the hollow lever, L, which runs to the bottom of the sphere to prevent the escape of steam.

Expansion Extractors.—One of the best apparatus of this class is that of Mr. Heintz, shown in section and



APPARATUS FOR EXTRACTING WATER OF CONDENSATION.

with water, and consequently descend and open an orifice through which it communicates by a tube.

Belonging to the first of these systems is Mr. Sainte's extractor, shown in section and plan in Fig. 1. This consists of a cast iron box, R, provided with a cover and containing a spherical float, F, connected by a lever, L, with an axle, *a*. This latter passes from the interior to the exterior of the box, and is provided with a conical appendage that makes a joint against the nut through a small spring, *r*, which bears against a needle, A, fixed to the extremity of the axle. The other extremity turns upon the point of a screw, *v*, which engages with a bronze nut provided with small apertures, so that when the screw is revolved a little, the air or gas contained in the box may be expelled. Through a rod, *t*, the lever, L, is connected with the valve, *s*, which, when it is lifted by the float, gives exit to the water of condensation that enters through T. A screw plug, *b*, allows of the apparatus being cleaned.

The extractor of Messrs. Dreyer, Rosenkranz & Droop, shown in vertical section in Fig. 2, consists likewise of a cast iron box, R, having a cover, C, provided with an air cock, *r*. In the interior is a float, F, which is here connected directly with the valve, *s*, through a rod, *t*. The valve, which is accessible through the cover, C, consists (see Fig. 3) of a sort of bronze box mounted, through a hinge, upon the eduction tubulure, and provided with a thick leaden washer not easily displaced. It can be maneuvered from the outside by means of the handle, A. When the water accumulates in the box, it lifts the float, and the latter, through its rod, opens the valve, whose orifice is always submerged in order to prevent the escape of steam.

The McDougall extractor, shown in Fig. 4, consists of a horizontal cylinder, R, cast in a piece with the tubulures, T and T'. In the interior, upon a support, *d*, there is mounted upon a knife edge a lever, L, from one end of which is suspended the float, F, and from the bulure, T', and, as the liquid can enter the float through the aperture, *f*, it naturally flows to the bottom, as shown by the dotted lines. In descending, it causes the screw, *v*, to turn through the pipe, L, and in consequence of the recoil motion of the screw, the valve, *s*, leaves its seat, and the water of condensation in the conduit is forced into the float through the pressure of the steam. It afterward flows into the reservoir through the tube, *t*, and strikes against the bell, *c*, the sole object of which is to prevent the water from being projected against the cover, C.

The Royle extractor, shown in Fig. 7, operates somewhat like the preceding. The float, F, is here a copper box of rectangular form, rounded above and open beneath. One of the sides contains an aperture which receives the plug of a cock, S, whose shell is fixed to the reservoir, and, through a threaded tubulure, communicates with the conduit to be emptied. Upon the rounded top there is arranged a plate containing two apertures covered by a small slide valve, *a*, connected with a lever, *a'*, whose center of oscillation is a piece fixed within the reservoir. The aperture is so arranged that when the float is raised the valve, *a*, closes the orifices, and when it is lowered the latter are open.

The Losenhausen extractor, shown in Fig. 8, operates identically the same as Royle's. The float, F, consists of a rectangular copper box open above, and its alternating oscillating motion, caused by the water of condensation and the steam entering through the tubulure, T, instead of operating a cock, lowers or raises a rod, *t*, which opens or closes an orifice in the axis of a bronze tube, B, screwed to the cover of the reservoir, R. This tube serves at the same time as a fixed center of oscillation for the float, through a brass ring screwed to its base and carrying the hinge that connects the plug, *f*, fixed by a nut and screw to the bottom of the float.

The Nacke extractor, shown in Figs. 9 and 10, contains an open float whose action upon the eduction plan in Fig. 12. Here we have a metallic tube, A, closed hermetically and acting under the influence of a special liquid contained in it and extremely sensitive to the heat of the medium in which it is situated, that is to say, to the temperature taken by the box, R. One of the extremities of this tube is connected with the cover, C, and the other with a bent lever, *l*. This latter is in contact with a second lever, L, jointed to a small oscillating frame, *c*, and located directly beneath the eduction valve, *s*. The extremity of the frame, *c*, bent at right angles, is provided with a nut with which engages a regulating screw, *v*, which passes through the cover, C, and receives a small winch, *m*. On revolving this latter we regulate the valve and consequently the exit of the water of condensation. In the front part, B, of the apparatus, there is a filter, *b*, to prevent the ingress of foreign substances.

The Dreyer extractor, shown in Fig. 14, is the type that offers the greatest simplicity. Its operation is based upon the expansion of a copper tube, A, open at its extremities. Through its upper part, screwed into the flange of the cast iron jacket, R, it communicates with the conduit to be emptied, and at its lower part it receives the eduction valve, *s*, the height of which is regulated by means of a threaded rod, *t*, terminating in a hand wheel, V.

When the tube is full of water, it is relatively cold, and the height of the valve is so regulated as not to stop the orifice, thus allowing the water of condensation to escape through the tubulure, T'; but, as soon as the steam has replaced the water, the temperature rises, and the tube, in expanding, presses against the valve and closes the communication.

The Cleuet extractor, shown in Fig. 15, consists essentially of a tube, A, fixed by its upper extremity to the iron plate support, R, and its other extremity, which is free, carries a bronze piece, T, cast in a piece with the entrance and exit tubulures, *t* and *t'*. In the

interior of this piece, in the axis of the tube, is mounted the eduction valve, *s*, which is held upon its seat by a spiral spring whose tension is regulated at will by means of a nut, *e*. Two other nuts, *e'*, screwed upon the valve rod, and bearing on the lever, L, movable around the axis, *a*, determine an automatic operation, as follows: As long as the tube is filled with steam only, the valve, *s*, is closed; but when the water of condensation, on accumulating, rises in the tube, a cooling results that makes the latter contract. On another hand, as the temperature of the iron support, R, has not sensibly varied, the lever, L, revolves around the point, *a*, which becomes the center of oscillation and causes the valve to open. The water then flows freely until the steam that enters the tube, A, brings it back to the temperature at which it resumes its initial length.

The Huhlmann extractor, represented in Fig. 16, is likewise based upon the effects of expansion and contraction; but, in arrangement, it differs entirely from the two preceding apparatus. In this extractor, the tubes, *a*, do not serve for leading the water and steam, but are surrounded thereby and externally undergo the effects thereof, placed, as they are, in the interior of the reservoir, R. The tubes are four in number and are coupled by a rod that connects them at the two extremities. The rods, *b*, are formed of a metal of feeble expansibility, while the tubes, *a*, on the contrary, are very expansible. The upper pair is connected with the threaded regulating rod, *t*, which is maneuvered through the hand wheel, *v*; and the lower pair is provided with an eduction valve, *s*. Guides in the interior of the reservoir permit of the tubes and rods being kept in the axis and of moving in an exactly vertical direction to open and close the valve, according as the water is filling the reservoir, or as the latter has expelled the steam that replaces it and expands the tubes and closes the valve.

This apparatus is combined with a drier, that is to say, the steam that traverses it meets with a projection, C, cast in a piece with the cover. This arrests the water that is carried along, and that traverses the filter, *l*, to reach the interior.—*Publication Industrielle.*

PHOTOGRAPHIC NOTES.

Instantaneous Photographs.—Both amateurs and professionals are daily obtaining more and more interesting results in measure as the sensitiveness of gelatino bromide of silver increases and the rapidity of shutters augments. We often receive curious specimens of instantaneous photographs, and we have already reproduced several of them. We cannot resist the pleasure of reproducing on the present occasion two very successful photographs taken by a skillful operator of Brussels, Mr. Alexandre. They represent a horse and his rider leaping over an improvised barrier. These photographs, which are very clean as regards execution, are worthy of examination from an artistic standpoint. One of them (Fig. 1) is exceedingly effective as regards design. The horse, with his legs drawn up, is full of movement, and the gesture of the rider raising his whip is exceedingly happy. A painter might get inspiration from this picture. The second photograph (Fig. 2), on the contrary, gives one of those attitudes produced by motions that our eye does not perceive, and which seems to us to be wanting in naturalness. The horse's tail, which is very stiff, stands upright in the air, and the two fore legs, absolutely straight, produce an effect that would not seem natural did we not know that we have before our eyes a reproduction of nature itself. Instantaneous photography is always very curious to study from an æsthetic standpoint.

Photographic Finder.—Fig. 3 represents a photographic apparatus, D, above which there is a finder, CB, of a new system. This finder consists of a small camera provided with an objective and, internally, with a mirror inclined at an angle of 45°, which reflects the image transmitted by the objective to a horizontal plate of ground glass. The object of this little apparatus (represented closed at A, and open at CB) is to permit of finding the object that it is desired to photograph, and to focus the image of it while the sensitized plate is in place. It is useless if artistic photographing or posing is being done, but it is necessary for the traveler who wants to take a single view and especially a natural motion on the instant. For example, when a negro sees an objective pointed at him he runs, or else he stands amazed, and every natural motion disappears. With the little apparatus here illustrated, the operator focuses while appearing to almost turn his back upon the object that he is photographing, or at least while bending his head down, without looking at the object. All explorers will recognize the advantages of this apparatus, which was invented by Mr. De Sanderval.—*La Nature.*

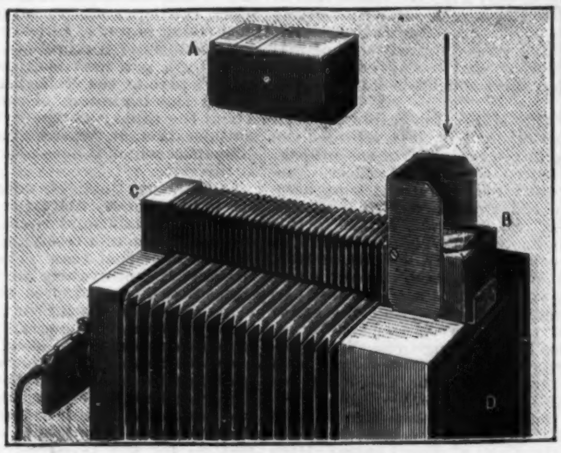


FIG. 3.—PHOTOGRAPHIC FINDER.

FIG. 1.—INSTANTANEOUS PHOTOGRAPH OF A HORSE AND RIDER LEAPING OVER A BARRIER.

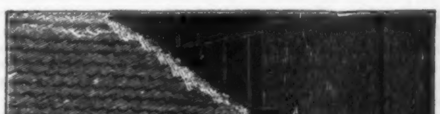


FIG. 2.—ANOTHER POSITION OF THE HORSE AND HIS RIDER.

THE ELECTRICAL DISTRIBUTION OF TIME.*

By ALLAN D. BROWN, Commander U. S. Navy, Assistant Superintendent of the Naval Observatory, Washington.

THE subject upon which I have the honor to address you this evening is the electrical distribution of time. Leaving out of consideration the question as to what time is, what its measure and how obtained—questions the answers to which would of themselves serve as a subject for an evening's lecture—I will pass at once to a definition of the title which has been chosen for this address. By this title is understood the causing of the instant shown by a timepiece at a central station to be marked, by some apparatus prepared to receive the necessary signal, at another station in electrical connection with such central station.

If the apparatus at the receiving station is in the nature of a timekeeper, its operation must be automatic; and to secure the highest possible accuracy, the action of the central timepiece must likewise be automatic. In its best form, then, our title may be said to mean the automatic electrical synchronization of one or more clocks by a clock at a central station; with this synchronization may also be associated the registering of the signal upon a chronograph, the ticking of a telegraphic instrument, the firing of a gun, the ringing of a bell, the discharge of a flashing signal, or the dropping of a time ball; in a complete system any or all of these means will be used, according to the circumstances of the case under consideration. It is essential, to insure the highest order of accuracy, that the central station shall always be at an astronomical observatory, and preferably at one which is able to devote the services of one or more persons to this special duty. Such work is known briefly as a time service, and its signals as time signals. A brief historical review of the evolution of the time service of to-day will not, it is hoped, prove uninteresting.

As early as 1816, one Ronalds, an Englishman, invented a telegraph which was so dependent upon timepieces for its working that it may be said to have been a device for the temporal distribution of electricity. He connected two clocks with some 500 feet of insulated copper wire; upon the seconds arbor of each clock was placed a circular plate of brass, the circumference of which was divided into twenty equal parts, the chief letters of the alphabet and a double series of numbers up to ten being placed in these divisions. In front of this was a second plate in which was an opening through which one letter and figure were visible; in front of this latter plate was suspended a pith ball electrometer connected with the wire between the two clocks and also with a frictional electric machine; this apparatus was in duplicate, one for each end of the line. An electrical pistol was also in circuit when the apparatus was not in use, so that by its discharge the attention of the attendant would be attracted when desired. The manner of using this telegraph was as follows: The clocks were first supposed to be accurately synchronized, so that the same letter would appear at the same instant in both plates; the machine was turned, and by the electricity thus generated the pistol at the other end of the line was discharged; the attendant in reply made a signal previously agreed upon, by waiting until this prearranged letter was in sight and then turning his machine, when the charge would cause the pith balls of the electrometer to diverge at both stations; the first operator would cause the discharge of the machine by a touch, the pith balls would fall together; the message would then be sent in like manner as each letter came in sight through the hole in the upper plate, the receiver noting each letter as the balls fell. There were two difficulties in the way of the use of this plan: (1) that of obtaining a current at all times; (2) the fact that it would be impossible to keep the two clocks always exactly together; this, however, could easily have been gotten over, as the sender could signal when a certain letter was visible, and the receiver noting the one he saw, could then tell how much his clock was out of the way. In effect this was the first attempt at telegraphic time signals, and for this reason only is it here referred to.

In 1833, the German mathematician Gauss, associated with Weber, erected a line of telegraph some five miles in length, connecting the astronomical and magnetic observatories in Gottingen with various other stations. He obtained his current from a crude form of magneto-electric or dynamo machine, and the whole apparatus was of a very unwieldy character; a flattened coil containing some 30,000 feet of iron wire had suspended within its center a magnetized bar weighing some thirty pounds; upon the suspending wire was arranged a mirror in which was reflected a scale, the latter being viewed through a magnifying glass.

The dynamo had a pole changer, so that the current could be sent in either a positive or a negative direction, and thus the bar be deflected either to the right or to the left at the will of the operator; by a combination of these deflections a message could be spelled out. By this apparatus, as I have gathered, comparisons of clocks were actually made, and to these gentlemen is therefore due the honor of sending the first telegraphic time signals. Although no particulars of the way in which this time service was operated are on record, it may easily be surmised that the method was somewhat as follows: Probably the hour selected for the signal was noon; two or three minutes before that hour by the standard clock, a signal would be sent over the line; as the hands of the clock marked the exact hour, one distinct deflection of the bar would be made, at which instant the receiver would note the time shown by his clock; subsequently ascertaining the error of the standard, that of the other would readily be deduced.

In 1840, Mr. Charles Wheatstone announced the invention of an apparatus "enabling a single clock to indicate the same time in as many different places, distant from each other, as might be required." He proposed to accomplish this object by connecting electrically a standard clock with his *electro-magnetic clock*, which latter consisted "simply of a face with its second, minute and hour hands, and of a train of wheels which communicated motive power from the arbor of the second hand to that of the hour hand in the same manner as in an ordinary clock train;" a small electro-magnet was caused to act upon a peculiarly constructed wheel placed on the seconds arbor, in such manner that whenever the temporary magnetism was either produced or destroyed, the wheel (and consequently the second hand) advanced the sixtieth part of its revolution. On the axis of the scape wheel of the primary clock was placed a small disk of brass, which was first divided into sixty equal parts; each alternate division was then cut out and filled with wood, so that the circumference consisted of thirty alternations of wood and metal. A very light brass spring was secured to an insulator attached to the clock frame, its free end pressing upon the circumference of the disk; connection having been made between the insulated end of the spring and one end of the wire with which the electro-magnet was wound, the circuit was completed by the other end of the wire being connected to the clock

* A lecture delivered before the Franklin Institute, January 13, 1888. From the *Journal* of the Institute.

frame through a battery; the primary clock being running, it followed that the circuit was made and broken each alternate second, while the distant dial recorded the advance of its wheel in unison with that of the parent clock. This is practically the same thing as the so-called electric time system of the present day, and it was the first attempt at the distribution of time by electricity It had the defect common to all such systems of being applicable to only a limited space, and in addition it was subject to the same trouble that besets every one who proposes to rely upon electricity derived from a battery as a motive power for any sort of machinery; accidents *will* occur, and in a system of time distribution on this plan an accident is fatal to precision.

The completion of the Morse telegraph between Washington and Baltimore, in May, 1844, afforded the means for the next step in the evolution of our subject, and for this we are indebted to a naval officer, Commander Wilkes (afterward rear admiral), who, associated with Lieutenant Eld, transmitted time signals between the two cities. So keen was Wilkes in this matter, and so alive to its importance, that although the telegraph was not completed until the 27th of May, yet, on the 9th of June, Wilkes was exchanging his first signals, completing his work on the 12th. He used two chronometers, each rated to local time, and thus ascertained the difference of time between the two cities, and hence the difference in their longitude; his determination of this difference was only 3-100 second from that subsequently determined by the Coast Survey when more accurate methods had been devised.

Two years later, in October, 1846, time signals were exchanged between the Naval Observatory, in Washington, and the observatory of the Central High School, in Philadelphia, this being the first use of what has since come to be known as the American telegraphic method of determining differences of longitude. This work was planned under the Coast Survey, by Mr. Sears C. Walker, an assistant in that office. The observations were made by Prof. Kendall, in Philadelphia, and Lieutenant Almy, in Washington.

In July and August, 1848, signals were exchanged between the observatory of Harvard College and a private observatory in New York. During this work, Prof. Bond, of Harvard, conceived the idea of an automatic circuit interrupter to be worked by the clock used in the observations. He communicated his ideas to the superintendent of the Coast Survey, and by him was authorized to construct a clock after his plans. This work was not finished until some time in 1850.

In the meantime, Mr. Walker, in conversation with Prof. O. M. Mitchell and Dr. John Locke, of Cincinnati, had told them what the survey desired in the way of an automatic registration apparatus. Both these gentlemen set to work, and Mitchell devised an apparatus which was finally completed in February, 1849. Locke busied himself in the same direction, and twelve days after his talk with Walker he had perfected his apparatus. In this each of the sixty teeth of a wheel on the seconds arbor of a clock struck the arm of a tilt hammer. When the tooth was in a horizontal position, the other arm of the hammer fell upon a bed of platinum, which was in connection with one pole of a battery, while the fulcrum on which it moved was in connection with the other pole. The circuit was then broken and made at each rising and falling of the hammer. The next step was to connect the clock with some form of registering apparatus, and for this purpose the ordinary Morse register, with its continuous fillet of paper, was used. On the 17th of November, a little more than three weeks after the idea was first suggested to him, Locke had in operation his clock, registering its beats over the entire line between Cincinnati and Pittsburg, a distance of more than 400 miles.

This was the first instance in which time signals were delivered *automatically*, by telegraph. As the fillet of paper passed through the register, a continuous record of the seconds was made, with nothing, however, to indicate the beginning of the several minutes. This indication was accomplished by the use of a break circuit key, which the observer held in his hand, and pressing at the sixtieth second of each minute, caused the registration to cease for three or five seconds, as might be desired, thus marking the beginning of the minutes. Presumably Locke was engaged during the following six weeks in perfecting his invention, for it was not until December 30 that he announced to Lieutenant Maury, the superintendent of the Naval Observatory, what he had accomplished, and offering it not only for the telegraphic determination of longitudes, but also "as useful in a local observatory as a faithful and convenient register of observations." On the 5th of January, 1849, Maury replied in substance as follows: "I regard it as one of the most important inventions of the age. Feelings of professional pride give additional zest and warmth to these congratulations. For ages the problem of longitude has occupied the minds of wise men, and commanded the attention of governments. This discovery of yours is the crowning work in the great problem. Permit me to claim this high honor first for my country, and next for the navy. An American naval officer, Capt. Wilkes, was the first to apply the magnetic telegraph to the practical determination of longitude. It greatly lessened labor and refined results. The next and last step has been made by yourself, who also are an ex-officer of the navy. You have, by your invention, eliminated from the problem the errors arising from comparing the face of one clock with that of another, and made it as easy and practicable to divide seconds into hundredths as before it was to divide minutes into seconds. By your invention you enable the astronomer to make the ticks of his clock here in Washington to be heard wherever the telegraph leads, and you make the clock to divide those seconds into hundredths."

On the same day he addressed a letter to the secretary of the navy informing him of Locke's invention, and recommending it in the highest terms. This letter was made public, and, after some further correspondence, it was followed by an invitation from the secretary to Locke to come to Washington. The subject of an appropriation was discussed, and, after much push on Maury's part, the sum of $10,000 was put in the naval bill by the House, for the purchase of a clock on Locke's plan. This came very near being lost in the Senate, but it was saved by the exertions of the friends of the measure, and became a law on the 3d of March. By the provisions of the act the clock was to be erected at the Naval Observatory. This was done, and, on the 7th of December, 1849, the clock, with the chronograph attachment, was used for the first time, and proved to be a great advance over the old method, although there was still some difficulty in the matter of accurate registration.

As before stated, in 1850, Prof. Bond, of Harvard Observatory, completed his clock for the Coast Survey, and in addition invented an improved chronograph in which the paper was placed upon a revolving cylinder, the driving power of which was so adjusted as to cause one revolution per minute to be made, the record being made by a pen in a continuous spiral line, but, as in Locke's plan of the Morse fillet, there was no means of noting the beginning of each minute automatically. About the same time the cylindrical form was under consideration at Washington, but there were some difficulties which it does not appear were surmounted at this date.

In 1851, the Bond chronograph, with its ingenious driving machinery known as the spring governor, was taken to England and there exhibited, eliciting much commendation and receiving a gold medal at the great exhibition of that year. The astronomer royal, of the Greenwich Observatory, in his report for June, 1851, states that he has adopted the plan of "making a galvanic register of transits in the American manner," but the cylindrical chronograph was not adopted until some three years later—a suggestion by Maury during a visit to Greenwich having enabled Sir George Airy to overcome the practical difficulties encountered.

During this same year, the observatory at Harvard was connected with the various telegraph lines from Boston, as many longitude operations were being carried on for the Coast Survey. In this manner the attention of such portion of the public as were interested in such matters was drawn to the practicability of obtaining accurate time from the observatory, and in many cases regular arrangements were made for the transmission of the signals throughout Massachusetts and some of the other New England States. Indeed, at present, the time service of Cambridge furnishes the chief source of comparison in that section of the country; the observatory of Yale College also possesses such a service, which supplies Connecticut in like manner. The observatory of the Washington University at St. Louis, and that at Allegheny, Pa., also have extensive time service, and there are others covering less ground.

At Washington the naval observatory has dropped a time ball since the first occupation of the completed buildings in 1844, following the example set at Greenwich, eleven years earlier. At first the dropping was done by hand, upon signal received from the chronometer room; later this signal was sent electrically, and the dropping of the ball was performed automatically by the same signal. This ball served to give the moment of noon not only to the cities of Washington and Georgetown, but also to the Navy Yard and to such vessels as happened to be lying there. No telegraphic signals were transmitted, however, for several years, the Royal Observatory at Greenwich far outstripping us in that respect, as a system of time signals to the important cities and towns of England was in operation as early as 1852. This, of course, was readily accomplished in a country of such small extent, where the difference of any given local time from that of Greenwich is not great, but in our own case the great extent of longitude and the different local times kept through what was supposed to be the necessity of the case, conspired to prevent the extension of any such system. Local jealousies had also a part to play in the matter, as the railroads running out of Boston would not keep New York time, and *vice versa*.

With this brief retrospect of the course of events which has made the electrical distribution of time possible, let us return to the subject proper of this essay, and in so doing I beg leave to repeat a portion of the definition with which it began, viz.: "By the electrical distribution of time is understood the causing of the instant shown by a timepiece at a central station to be marked by some apparatus prepared to receive the necessary signal at another station in electrical connection with such central station. It is essential, to secure the highest order of accuracy, that the central station shall always be at an astronomical observatory, and preferably one which is able to devote the services of one or more persons to this special duty." In order to a fuller understanding of the functions of an observatory, it will be necessary to call your attention to some of your early instruction in astronomy. The interval between two successive transits, or meridian passages, of the sun, is an apparent solar day; owing to the unequal motion of the earth in its orbit (or to put the statement in another form, to the apparent unequal motion of the sun in the ecliptic), two successive apparent days are not of the same length. As a constant standard of time is necessary, it has been found essential to assume an imaginary sun moving in the equinoctial (or the plane of the earth's equator) at a uniform rate, which is the mean rate at which the true sun moves in the ecliptic; the interval between two successive transits of this imaginary mean sun is a mean solar day, and in a clock keeping mean time, the hands would (if the clock were correct) point to 12h. 0m. 0s. at the instant of transit, which is known ordinarily as noon. As a matter of fact, however, the sun is rarely used at observatories for the determination of time, but stars are employed instead; this is done, not only because the tables of the positions of the stars are more accurate, but because several stars can be observed at about the same time and the results deduced from these observations made to serve as checks upon each other. The interval between two successive transits of the same star is called a sidereal day; this interval is constant, and is (like the mean solar day) divided into twenty-four hours. Each star comes to the meridian at an earlier period than on the day preceding, if the transit be noted by a mean time clock; the difference between a star and a sidereal day is 3m. 56·56s., and hence the sidereal 0h. is constantly getting ahead of the solar 0h., so that it is always necessary to reduce the *sidereal* time found by the star observations to that used in ordinary life, or to *mean* time. The positions of stars are given in the tables by their *declination* (similar to terrestrial latitude) and their *right ascension* (similar to terrestrial longitude); the right ascension of the star being reckoned from the celestial prime meridian, it follows that when any given star crosses the meridian, the sidereal clock should show the time given in the table as the right ascension of such star; the difference between the time actually shown by the clock and this right ascension is the error of the clock; comparing then the time shown by the sidereal clock with that shown by the mean time clock, we find the error of the latter. This is briefly the method followed by all observers, and hence is common to all systems of time signals. We have, then, as essentials of any such system: (1) an instrument for observing the transits of stars, (2) a sidereal clock, and (3) a mean time clock. This mean time clock (like all timepieces) will not run accurately, its rate varying, being sometimes less and sometimes greater; the pendulums of such clocks are generally very well compensated for changes of temperature, but it has been found that the density of the air has a decided influence upon the rate at which the clock runs; when the barometer is high, the clock loses on its rate, gaining when it is low. In order, then, that the time which is sent out over the wires should be correct, it is necessary either to have some arrangement for correcting the standard mean time clock so as to make it correct, or else to have a similar clock which can be likewise corrected; such a clock is known as a transmitter.

The system of the Greenwich Observatory being the oldest in point of time, merits the first description. The standard sidereal clock is a remarkably fine piece of workmanship, having, in addition to a peculiarly constructed compensated pendulum, an auxiliary apparatus intended to still further aid in the compensation for changes in temperature, which it would be impossible to describe intelligibly without a drawing. There is also an arrangement for counteracting the influence of the variations in the density of the air, which is the invention of Sir George Airy, and is very ingenious; two bar magnets are secured to the bob of the pendulum diametrically opposite each other, one with the north pole down, the other with same pole up; below these at a distance of about four inches is a horseshoe magnet which hangs on one end of a walking beam, to the other end of which is attached a float resting on the surface of the mercury in the cistern of a specially constructed barometer; with a rise in the barometer the horseshoe magnet rises nearer the bob, and thus exerts a stronger influence upon the swinging magnets, causing the pendulum to oscillate more rapidly; the contrary takes place when the mercury falls. Notwithstanding all these refinements, the published records of the observatory show that the clock does not run with perfect accuracy, a variation of its daily rate as large as 1·15 seconds being recorded in a year. It does, however, run with but slight variations of rate from day to day; still it shows as great a loss as one minute in six months; it is supposed to be regulated to lose a small amount daily, but the records show that it occasionally gains as much as half a minute in five or six months. I mention this here in order to show you that those people who talk about their clocks or watches running to within a few seconds a year are probably somewhat wide of the truth. This standard sidereal clock registers its beats upon the chronograph used in observing transits, controls the remaining sidereal clocks in different rooms of the building, and finally drives (in unison with itself) a sidereal chronometer. The controlled clocks are upon the Jones system (as modified by Sir George Airy); in this system the secondary clocks are required to be quite as good timekeepers as the primary one, which makes it too expensive for general use among the public. As used at Greenwich, the standard clock closes a circuit in which the controlled clocks are placed, every second; on the pendulum of each of these latter is a magnet, which, at the end of its swing, enters a coil of insulated wire; as the current passes, the effect is to hold the magnet within the coil, and hence to place the pendulum in a definite position, which corresponds in effect to that of the pendulum of the primary clock; this closes the circuit by means of a wheel on the seconds arbor, which presses upon a spring at each forward motion. The sidereal chronometer, already spoken of in this connection, is constructed practically upon the same principle as those of Wheatstone, referred to in the early part of these remarks. This sidereal chronometer is in the time service room, and is used for the purpose of comparison with a similarly constructed mean time chronometer which is driven by the mean time clock now to be described; this is essentially a galvanic clock of peculiar construction, and of which I imagine there are but few existing. As the pendulum swings to the right, it closes a circuit through the coils of an electro-magnet which actuates a peculiar mechanism, by which, as the pendulum swings to the left, a weight is caused to impinge upon the pendulum, thus giving it the impulse which in an ordinary going clock it receives from the weight or spring; this impulse is given at each alternate vibration. At each extremity of the swing of the pendulum it closes a circuit, which, acting upon the coils of two electro-magnets, alternately attracts and repels the opposite ends of a balanced polarized armature. This rocking motion is readily converted into a rotary one, causing the seconds hand to revolve, and, by the usual device of a train of wheels, the minute and hour hands also. There are several clocks driven by this pendulum, including the mean time chronometer just mentioned as being in the time service room. The apparatus for correcting the error of the standard mean time clock consists of a magnet secured to the pendulum which swings over a hollow coil of insulated wire attached to the clock case; if a current be passed through the coil in one direction, the magnet on the pendulum is attracted and the oscillations are more rapid. If a current be sent in the opposite direction, the contrary is the case. A switch in the time service room serves to operate this arrangement when desired, and the battery is so arranged that it will accelerate or retard the pendulum at the rate of one-tenth of a second in a minute.

The practical working of the observatory portion of the time service is as follows: The error of the standard sidereal clock is obtained by means of star observations as before described. At 9 A. M. daily the mean time and sidereal chronometers in the time service room are compared by what is known as the eye and ear method; that is to say, the observer waits for the coincidence of the beats of the two instruments and notes the time shown by each at this instant; applying the error of the sidereal clock to the time shown by the sidereal chronometer, the correct sidereal time is found; by a

comparatively simple operation the corresponding mean time is found, and from this the error of the mean time chronometer, or what is the same thing, the error of the standard mean time clock. Suppose that this clock is found to be one second slow; the switch to the coil in the clock is turned in the accelerating direction for ten minutes, during which time the pendulum is swinging faster than usual, and at the end of this period the clock has gained the necessary second; and not only the standard, but all the clocks that are driven by it.

In this condition the standard is in readiness to be used as a transmitter; it is in a circuit which is closed automatically every hour by the operation of wheels within the clock itself. The closing of this circuit operates a relay which transmits a single beat (that of 0 minutes and 0 seconds of the exact hour) to the general post office in London, and also to the station of the railway leading to Deal. At this latter point a time ball is erected and is dropped by the hourly signal sent at 1 P. M. The hourly signal is also transmitted over certain private wires belonging to various jewelers, for the purpose of comparing their timepieces. In one case, at least, this signal is also used for purposes of distribution, as will be noted further on. The line to Deal is for a short time virtually under the control of the observatory, so that a return signal is sent which announces the fall of the ball. A very ingenious adaptation of the galvanic clock described as the mean time standard is in use on this circuit. At a certain point where the line to Deal is looped in, this second clock is placed. It is regulated so as to have a gaining rate of several seconds, so that at 1 P. M. it is always too fast. When that hour is shown by the clock, the circuit which operates the electro-magnet and thence the clock train is switched out automatically, and the Deal loop is switched in; the pendulum continues to swing until the passage of the signal from the observatory opens the circuit, and the clock then moves on, showing the exact Greenwich time as it starts.

From the General Post Office the time is distributed in the city of London hourly and throughout the country at 10 A. M. and 1 P. M.; the arrangement for this distribution is very elaborate, there being four groups of circuits, each worked by a separate relay, which is itself worked by the hourly signal from the observatory. The lines within the city, being used for time purposes only, are always in circuit; the country lines, however, are used for ordinary commercial purposes; hence, it is necessary that they should be cut out just before the times at which the signal is to be transmitted; this is accomplished automatically by a specially constructed clock which opens the relays about two minutes before the hours of 10 and 1, thus clearing the lines for the reception of the signal; about ten seconds after its passage, the relays are closed by the action of the clock. It will be observed that the signal sent over the wires is but a single beat, and is, therefore, of a character that would hardly be suitable for use in this country of magnificent distances. All of the time service work outside the observatory (except that of the Deal ball) is under the supervision of the post office department, and a large number of persons are thus supplied with the Greenwich time direct; in many cases the signal is repeated by local operators to smaller offices, so that, practically speaking, the standard time of the country is dispersed throughout England, Scotland, and Wales; in Ireland, Dublin time is the standard, and Greenwich time is used only for purposes of comparison.

In addition to the time ball at Deal, a like ball is dropped daily at the same hour (1 P. M.) from one of the turrets of the observatory; this ball is the oldest in existence, having been first dropped in 1833. Time guns are fired by the same signal at Newcastle and North Shields.

Reference has been made to the distribution of time by private parties in the city of London; this is done by the firm of Barraud & Lund, whose system is one of much ingenuity. In it ordinary clocks are provided with an attachment by which the error of the clock can be corrected at any exact hour, provided that this error does not exceed two minutes. In the central office is a mean time regulator provided with means for correction of its error by an electrical attachment similar to that in use at the observatory in Greenwich; the error of the standard is ascertained by a comparison of the signal received from the observatory at each hour with the beats of the regulator, which are registered upon a chronograph. The regulator is corrected when necessary, and sends automatically a signal over all the lines leading from the office at 0 minutes and 0 seconds of each hour. The signal actuates the armature of an electro-magnet in each clock; from this armature are projecting arms which make a sliding connection with the setting pins which protrude through a slot in the dial, and act like a thumb and finger to bring the minute hand to the 0 position; the arms have a counterpoise which serves to bring them back to their normal position when the current ceases; the contact in the regulator clock is not instantaneous, but prolonged for some seconds in order to be sure of effecting the desired correction. Combined with these synchronizing clocks are audible and visual signals, the first being made by a bell, the second by a revolving disk which shows alternately red and white; such a signal is used in the London Stock Exchange; but it would seem to have the disadvantage of requiring that attention should be directed to it for some time before its arrival.

In Liverpool, Glasgow, and Edinburgh, the Greenwich time is distributed by several clocks provided with the Jones system of regulation; at least this was the case up to a comparatively recent date.

In Paris, the observatory distributes the time to thirteen so-called horary centers, each of which is furnished with a secondary clock that is in itself a good and expensive timekeeper, and is regulated by the central clock through a modification of the Jones system. The central standard, besides being provided with the most approved compensation, has also upon the pendulum a small box in which light weights are from time to time placed or from which they are removed to restore the rate of the clock to the normal when it is found to have been disturbed. At each vibration of the pendulum the circuit is closed for a large fraction of a second and the current from the battery switched in; this animates an electro-magnet situated beneath the center of the arc of vibration, so that a piece of soft iron carried by the pendulum bob is attracted, and thus the clock (which is kept running on a gaining rate) is retarded; the adjustment is made so that the amount of retardation is just sufficient to keep the secondary clocks beating in unison with the primary. The secondary clocks send hourly signals automatically to various places in their immediate vicinity, thus distributing the time over a large area. I am informed, however, by a gentleman who has recently been in Paris and examined the subject, that this system is one that is not now depended on.

In various cities of the Continent the system of Hipp is used quite extensively; in this system a central or master clock drives a number of secondary ones, very much after the system used at Greenwich. In Berlin there are a few clocks regulated on the Jones system, but there cannot be said to be what is regarded as an efficient time service.

Some idea of the extent of the distribution of time from observatories in this country may be gathered from the statement that there are over 124,000 miles of railway thus supplied; of this number, the Naval Observatory at Washington supplies 29,000 miles; that of Allegheny, Pa., 24,000 miles; that of the Washington University at St. Louis, Mo., 22,000 miles; being a total of 75,000 miles; the remaining 49,000 are supplied by nineteen other observatories, two of which are in Canada.

The system used by all, except the Naval Observatory, is what may be called a continuous one; that is to say, the standard mean time clock records its beats—with certain omissions—upon various sounders connected with it. In some of these clocks the contact wheel on the seconds arbor is so cut as to send the signal every second, omitting certain seconds at the close of the minute, the beat following this pause marking the beginning of each successive minute; in others, only the even seconds are transmitted, with a similar arrangement for determining the beginning of each minute; some have every fifth minute noted by an omission of a different character, and in others a like omission marks the termination of the hour. It is evident that there is no way in which to mark any particular minute; in the fifth minute system the time can be identified by a distant receiver, provided he knows what fifth minute is being signaled—in other words, if he is sure of his time within two and one-half minutes; in the hourly system there will be evidently no trouble in recognizing the hour at its termination. As a rule, these observatories are connected by wire with the establishments of various jewelers and watchmakers in the immediate vicinity, as well as with the telegraph wires leading out of the city. At a certain prescribed hour—generally just before noon—the operator in the telegraph office switches his wires into connection with those from the observatory, and the beats of the standard clock are thus transmitted over a greater or less extent of country; the time thus received is used primarily by the railways, and secondarily by the jewelers and others in the towns through which the lines pass; in some instances these have sounders in their own offices; this is especially the case in the larger cities. In smaller towns, the signal is taken off the sounder in the office by comparison with a watch, which is itself afterward used as a means of comparing the regulator and thus ascertaining the error of the latter.

Generally speaking, the time received by the railways is only at their division headquarters, and later it is transmitted over each division wire by hand, the clock in the office being taken as the standard. The uniform train rules of the railroads now prescribe that the hours for the distribution of time shall be 5 P. M. Eastern time, or 4 P. M. central time.

The system adopted by the Naval Observatory at Washington is like that at Greenwich, in that signals are sent only at a certain prescribed time, viz., at noon of the seventy-fifth meridian. The practice at Greenwich of altering the standard clock, and sending its beats over the wires, is not, however, that used in Washington; there the standard clock is allowed to run on and accumulate its error without interference, a separate clock, called the transmitter, being used for the purpose of sending the time signals. This clock is compared at 11:40 A. M. daily with the standard, which has itself been compared with the standard sidereal clock at 9 A. M., as well as on the evening before, if observations have been made. If an inspection of the barometric and thermometric records shows no large fluctuations, it is assumed that the rate of the clocks has been constant; if such changes are noticed, however, allowance is made for them by the observer, in accordance with his judgment, derived from previous experience. This is, in effect, the same thing as is done at those observatories where the standard clock is used, only there this clock is altered by the use of weights upon the pendulum, while with us the error of the transmitter is ascertained, and then the latter is set to the correct time. Being thus set as nearly as possible—and this can be done to within the twentieth of a second by means of the chronograph—at three and one-fourth minutes before noon the clock is switched into the circuits leading from the observatory to the offices of the Western Union Telegraph Company, the signal service, and the fire alarm; the seconds transmitting wheel is so cut as to omit the twenty-ninth second, as also the last five seconds of each minute; an additional wheel is placed on the seconds arbor, having a peculiar shaped tooth which comes into play in the sixtieth second of each minute when the proper switch is turned; as the beats progress an observer at a distant station notices the omission of a single beat; by this he knows at once that it is the half minute signal; as some time must necessarily elapse before the signals reach stations so distant as Boston or New Orleans, it follows that all the signals will not be heard at all stations; hence it becomes necessary for the operator to take up the count at thirty, and keep it up until fifty is reached; if more ticks are heard, he is made aware that there is at least one more minute to come; should, however, the ticks cease at fifty, he knows that it is the last minute of the hour, and that the next signal will be that made by the transmitting clock as its seconds hand reaches the exact instant of noon. The sender at the clock at that time (ten seconds before twelve) switches out the seconds beat and switches in the minute one; as the seconds hand comes to sixty, the tooth before spoken of causes the current to pass, not merely for a fraction of a second, but for the whole of that time, thus not only distinguishing it from all other signals sent, but also insuring sufficient time for full contact of the armatures of all relays, time ball magnets, etc., reached by it. In connection with the observatory, reached over the wires of the Western Union Telegraph Co., are time balls at Wood's Holl, Mass., Newport, R. I., New York City, Philadelphia, Baltimore, Hampton Roads, Savannah, and New Orleans. A ball is also dropped on the navy department building in Washington, being connected with the observatory by a special wire.

The connections from the clock are briefly as shown in the diagram on the board: A two pt. repeater of peculiar construction is placed on top of the clock case, the circuit through the coils of its magnets and the points of the transmitting springs being normally closed; as the wheel already described revolves, these points are slightly separated; the circuit is broken and the armature released, the opposite end being drawn down by the tension of a spring, making a circuit through one of the posts upon which the lever strikes and an eight pt. repeater upon a table near by; this in turn makes a circuit through the eight wires leading from it when the proper switches are turned; the other post of the two pt. repeater is used only by dropping the time ball above referred to. The action of this repeater is peculiar, inasmuch as by it the seconds beat, instead of being of but an instant's duration, lasts about one-tenth second—a great advantage in the long distances over which the signal passes. The signal sent to the fire alarm office sets in motion an automatic apparatus, by means of which all the fire bells in the city are made to strike the hour, the first stroke being very nearly the instant of noon by the clock; of course, some allowance must be made for the action of the striking mechanism, but for all practical purposes the time thus given may be said to be exact. A like signal is sent at 7 A. M. and 6 P. M., and the bells struck at those hours.

The observatory has also in times past used the Jones system for the control of distant clocks with a very considerable degree of success, but, as has been the case at Greenwich, experience has led to the abandonment of all attempts at any service outside the observatory which require the continuous use of a wire and in which the clocks depend for their correctness upon the constant transmission of signals. As I have before said, the Jones system requires that the secondary clocks should be quite as good time keepers as the primary, which is in itself a grave objection on account of the expense involved. If from any cause there is a fault on the line (and I need not say that such faults are too apt to occur), the secondaries go on running each with its own error, so that when the line is repaired, the connections again restored, and the current passes, it is not only improbable that all the clocks will show the same minute and second, but in the highest degree probable that they will not do so.

As in these remarks I have assumed that an astronomical observatory must be the base from which time is to be distributed electrically, but little has been said concerning the various systems of so-called electric time which are now so much in vogue. So far as I am aware, no proposal has yet been made to use the clocks of any of these systems in other than detached groups, each having its own master or driving clock, which is not in connection with any source from whence correct standard time is derived; each master clock runs on at its own rate, so that no two of half a dozen groups will show the correct time. However practicable it might be to have such a system in a single town or a number of such in a large city, it is quite evident that on the score of expense alone it would be impossible for the observatory at Allegheny or Washington to be connected with such a system in this city; and hence the time furnished by it would not be reliable.

The idea of employing the electric current as a motor for clocks is one that is very entrancing, and that has been carried out with more or less success by the inventions of various persons; reference has already been made to the early system of Wheatstone, as also to that of Hipp, which latter is probably the one that is the most widely employed on the other side of the Atlantic, and to some small extent in this country. Probably most of you are familiar with the system in use in some of the stations of the Pennsylvania railroad, and if so, you are likewise familiar with the fact that not infrequently one or more of the dials is covered with paper to prevent its incorrect indications from misleading the public. That some of the dials should go wrong is almost inevitable, even where the lines are confined to a single building; and it may be added here that at Greenwich, where there is a similar system used, it has been found necessary to provide other clocks of the ordinary pattern, furnished with the necessary contact arrangements, for use in case of the failure of those operated by electricity. As the published reports of the observatory state that these extra ones are occasionally used, it is fair to presume that the others have not been found exempt from the failures to which all such arrangements are liable. I think that it may be safely said that experience has developed these facts: (1) that no machinery which depends upon a current derived from a battery for its motive power is reliable; (2) that no step-by-step apparatus can be depended upon always to perform its functions; (3) that nothing is more certain than that the wires connecting any series of buildings or towns will at some time get out of order. From these facts it can readily be deduced that electro-motor clocks are not to be relied on, except within a very limited sphere, and then only with the most constant and unremitting attention to all parts of the apparatus and connections.

There are undoubtedly some of these clocks that are better than others. One of the latest is that of Spellier, of this city. It would seem that in this plan a good many of the mechanical and electrical difficulties which surround the problem have been attacked with a reasonable degree of success, but you will observe in the specimen which is here shown, first, that the master clock is not of a first class character, being very likely to be affected in its rate by all sorts of influences, and further that it is not in connection with any source whence the standard time is derived. It is true that the time can be obtained from the telegraph office as it is sent from Washington, and the clock then set to correspond, but that is a method which requires too much time and attention. Secondly, you will notice that the secondary clock moves but once a minute, that is to say, that it is correct just once in sixty seconds (when I say correct, I mean in accord with the master clock), so that it is impossible to tell what time it is to within nearly a minute. For instance, when the hands of the

secondary point to five minutes past nine, the other clock may be at five minutes and fifty-nine seconds past. This may be considered sufficiently correct, but if a man was in haste to catch a train, he might be easily deceived by thinking that he had nearly a minute more than was really the case. The seconds hand has evidently been abandoned by the inventor of this system, as there is much less expenditure of battery power and certain mechanical difficulties are avoided. There are electrical difficulties also in the way of running a very large number of these clocks on one circuit.

For the reasons that have been cited above, the idea of sympathetic has been abandoned, by those experienced in their workings, for that of synchronized clocks. The system of Barraud and Lund, in use in London, has already been described. Even that, however, is hardly applicable to our own country, where it is not always possible to receive even a daily signal, for in London it has been found best to correct these clocks hourly.

It may be assumed as the result of many years' experience, 1, that electricity is the most suitable power for controlling clocks at a distance from a central standard, since it is the only available force which acts with sufficient quickness to avoid delay and insure accuracy; 2, that it must be used as a setting or controlling, and not as a motive power, inasmuch as sooner or later failures in the connections or breaks in the wires stop the clocks, and hence cause confusion to all who look to them for time; 3, that the cost of maintenance must be reduced to the lowest point, and for this purpose the wires must be in use as short a time as possible, and the least amount of force necessary to set the clocks right must be applied to the secondaries—this also involves the reduction of the amount of attention necessary to be paid to each clock to the lowest possible point; 4, that the system must be such that clocks of differing patterns can readily be included in the circuit, and that the correcting mechanism can easily be applied to them.

The system used in London fulfills these functions quite well within its limits, but it has its disadvantages in that its power of correction is limited to the minute hand only, and that for an error not exceeding two minutes. This system has been used at the Naval Observatory at Washington (as have others also), but none has been found to fully cover the requirements of the case until the adoption of the one now in use. This is the Gardner system, by which the correction is made to both seconds, minute, and hour hands, and in which there is no limit to the number of minutes that can be corrected, an error of twenty-five minutes being overcome as easily as one of twenty-five seconds!

The clock shown here is one such as we use in the observatory and on our clock line running to the various public buildings. One of the points of the 8 pt. repeater mentioned above is connected with this line. Where in air it is an insulated wire, elsewhere it is in the Waring cable. There are over eight miles in the circuit, and upon it more than 350 clocks. In each building entered by the line there is, of course, a local circuit, upon which as large a number of clocks as 100 are worked. There is no complaint as to the working of the system. During the three and a half years that it has been in operation, all our trouble has been upon the line. The clocks themselves and the correcting apparatus give us no anxiety. Now, it is quite plain that these line troubles would have caused a system of sympathetic clocks to have ceased operations entirely, while in this plan the clocks have gone on running, and as soon as the line has been repaired, by the simple turning of the proper switches the clocks have been corrected to coincide with the observatory standard. The Pension Office has seventy-five of these clocks, and quite recently the Patent Office (abandoning all others) has put in some 140. There are clocks of this pattern also in use at Newport, Hampton Roads, and Savannah, giving, so far as I know, perfect satisfaction, and wherever the observatory signal goes they can be used.

I had finished writing the foregoing remarks, and felt that I appreciated, to some degree at least, the necessity that exists for exactness of time, when this cutting from the *New York World* of January 1 was handed me. I will not weary you by reading it at length; suffice it to say that it discloses a most lamentable state of affairs existing in the public clocks of the great metropolis. The writer states that there is just one place where accurate time can be obtained, and that is from the time ball on the Western Union building, to see which drop hundreds of people assemble every week day hardly appreciating, probably, that the signal which drops the ball comes from the Observatory clock, over 200 miles away. When, however, ones goes up Broadway, and attempts to compare his watch with the various clocks that are to be seen, he will have, as the reporter says, "an interesting time." No two of them are alike, and often the different faces of the same clock are discordant. Even the clocks in front of the great jewelry establishments are rarely correct, though they are very imposing, in more senses than one. Here are some illustrations of the way in which New Yorkers are treated in this matter. The clock at the corner of Broadway and Twenty-first Street at noon showed twenty-five minutes past one! The one on the next block was a little nearer correct, showing but four minutes after twelve. The worst specimen of all was the one in the Fifth Avenue Hotel, which at high noon informed the guests of that establishment that the hour was twenty-five minutes past ten! Well may it be said that reform in this matter is imperatively necessary!

Now that we have the system of standard time in use, an observatory must necessarily be the source of this time, and it becomes more than ever important that communication with well established institutions of this sort should be regular and constant. There should be no such state of affairs as has been shown to exist in New York, nor is there any necessity therefor. The observatory at Washington was established on account of the needs of the navy for an accurate standard of time, and following the example of other government institutions, it naturally gives to commerce its assistance when needed. The time balls already alluded to are but the beginning of what it is hoped will be a comprehensive system embracing the whole coast, so that in every commercial city there shall be a like installation. All that is wanted is an appropriation of the money that has been asked for, and which it is to be hoped will be granted. Nor is this the only function of the observatory, as has been shown already in the statement of the extent to which its time signals are distributed. Its system is the result of much study and experiment, and is believed to be fully suited to the needs of the community which it can serve, scattered as it is over such wide extent of country, and necessitating such long distance transmission of the signals.

ON THE HEATING EFFECTS OF ELECTRIC CURRENTS.

On March 19th, 1884, Mr. Wm. H. Preece, F.R.S., submitted to the Royal Society a paper "On the Heating Effects of Electric Currents," showing the strength of current necessary to fuse the fine platinum wire employed for protecting submarine cables from the ill effects of atmospheric electricity. The paper proved that the law that regulates the production of heat is one which can be expressed by the formula $C = a d^{\frac{3}{2}}$, "a" being a constant dependent on the metal used, and "d" the diameter of the wire. The current observed was that which heated the wire up to the point of self luminosity—525 deg. C. Since "cut-outs" of the same character as the cable-lightning protector have become an essential feature of all electric-lighting installations, to act as safety fuses, when from accident or design an excess of current is allowed to pass through the conductor, it became most desirable to determine the current that would fuse wires of different diameters and of different materials, so as to determine the coefficient a for all the metals. The best material to use and the proper dimensions of the fusible wire to be employed for the protection of the electric-light conductors would thus be easily deduced. The wire to be experimented upon was clamped between two small brass-binding screws fixed upon a dry wooden stand.

Mr. Preece pointed out in his previous paper how the cooling effects of the terminals or binding screws might vitiate the results, and how necessary it was to experiment on wires of sufficient length to prevent any error occurring from this cause. He used lengths of 6in. to determine the constants for wires free from the cooling effect; but lengths of 1½in., with massive terminals, to determine the constants for wires used in practice as "cut-outs." The cooling effect of the terminals very seriously affects the efficiency of the cut-outs used in actual practice, and the larger the fusing wire and the terminals the more serious is the error introduced. On the other hand, the greater the lengths of wire used as a fuse the greater the resistance inserted, and the efficiency of the system itself may be reduced. Cut-outs, therefore, should be employed sparingly and with judgment, and the fusing wire should not be so short as to impair the fusing point. "When we consider, says Mr. Preece, "the irregularities in drawing these fine wires to true cylinders, the difficulty in determining the current at the exact moment of fusion, and the variation in the specific resistance of the metals, the results must be considered very satisfactory in support of the law."

The final values of the constant "a" arrived at by Mr. Preece and submitted by him in a paper communicated to the Royal Society on March 15th, are as follows:—

	Inches.	Centimetres.	Millimetres.
Copper	10,244	2530	80·0
Aluminium	7,585	1873	59·2
Platinum	5,172	1277	40·4
German silver	5,230	1292	40·8
Platinoid	4,750	1173	37·1
Iron	3,148	777·4	24·6
Tin	1,642	405·5	12·8
Alloy (lead and tin 2 to 1) ..	1,318	325·5	10·3
Lead	1,379	340·6	10·8

The three columns are the constants to be used when the diameter of the wire is given respectively in inches, centimetres, or millimetres. With these constants Mr. Preece has calculated the following very useful tables:—

Table showing the Current in Ampères required to Fuse Wires of Various Sizes and Materials. $C = a d^{\frac{3}{2}}$.

No. S. W. G.	Diameter, inches.	$d^{\frac{3}{2}}$.	Copper. $a = 10,244$.	Aluminium. $a = 7585$.	Platinum. $a = 5172$.	Ger. silver. $a = 5230$.	Platinoid. $a = 4750$.	Iron. $a = 3148$.	Tin. $a = 1642$.	Tin-lead alloy. $a = 1318$.	Lead. $a = 1379$.
14	0·080	0·022627	231·8	171·6	117·0	118·3	107·5	71·22	37·15	29·82	31·20
16	0·064	0·016191	165·8	122·8	83·73	84·68	76·90	50·96	26·58	21·34	22·32
18	0·048	0·010516	107·7	79·75	54·37	54·99	49·95	33·10	17·27	13·86	14·50
20	0·036	0·006831	69·97	51·81	35·33	35·72	32·44	21·50	11·22	9·002	9·419
22	0·028	0·004685	48·00	35·53	24·23	24·50	22·25	14·75	7·692	6·175	6·461
24	0·022	0·003263	33·42	24·75	16·88	17·06	15·50	10·27	5·357	4·300	4·499
26	0·018	0·002415	24·74	18·32	12·49	12·63	11·47	7·602	3·965	3·183	3·330
28	0·0148	0·001801	18·44	13·66	9·311	9·416	8·552	5·667	2·956	2·373	2·483
30	0·0124	0·001381	14·15	10·47	7·142	7·222	6·559	4·347	2·267	1·820	1·904
32	0·0108	0·001122	11·50	8·512	5·805	5·870	5·330	3·533	1·843	1·479	1·548

Table giving the Diameters of Wires of Various Materials which will be Fused by a Current of given Strength.

$$d = \left(\frac{C}{a}\right)^{\frac{2}{3}}$$

Current in ampères.	Diameter in inches.								
	Copper. $a = 10,244$.	Aluminium. $a = 7585$.	Platinum. $a = 5172$.	German silver. $a = 5230$.	Platinoid. $a = 4750$.	Iron. $a = 3148$.	Tin. $a = 1642$.	Tin-lead alloy. $a = 1318$.	Lead. $a = 1379$.
1	0·0021	0·0026	0·0033	0·0033	0·0035	0·0047	0·0072	0·0083	0·0081
2	0·0034	0·0041	0·0053	0·0053	0·0056	0·0074	0·0113	0·0132	0·0128
3	0·0044	0·0054	0·0070	0·0069	0·0074	0·0097	0·0149	0·0173	0·0168
4	0·0053	0·0065	0·0084	0·0084	0·0089	0·0117	0·0181	0·0210	0·0203
5	0·0062	0·0076	0·0098	0·0097	0·0104	0·0136	0·0210	0·0243	0·0236
10	0·0098	0·0120	0·0155	0·0154	0·0164	0·0216	0·0334	0·0386	0·0375
15	0·0129	0·0158	0·0203	0·0202	0·0215	0·0283	0·0437	0·0506	0·0491
20	0·0156	0·0191	0·0246	0·0245	0·0261	0·0343	0·0529	0·0613	0·0595
25	0·0181	0·0222	0·0286	0·0284	0·0303	0·0398	0·0614	0·0711	0·0690
30	0·0206	0·0250	0·0323	0·0320	0·0342	0·0450	0·0694	0·0803	0·0779
35	0·0227	0·0277	0·0358	0·0356	0·0379	0·0498	0·0769	0·0890	0·0864
40	0·0248	0·0303	0·0391	0·0388	0·0414	0·0545	0·0840	0·0973	0·0944
45	0·0268	0·0328	0·0423	0·0420	0·0448	0·0589	0·0909	0·1052	0·1021
50	0·0288	0·0352	0·0454	0·0450	0·0480	0·0632	0·0975	0·1129	0·1096
60	0·0325	0·0397	0·0513	0·0509	0·0542	0·0714	0·1101	0·1275	0·1237
70	0·0360	0·0440	0·0568	0·0564	0·0601	0·0791	0·1220	0·1413	0·1371
80	0·0394	0·0481	0·0621	0·0616	0·0657	0·0864	0·1334	0·1544	0·1499
90	0·0426	0·0520	0·0672	0·0667	0·0711	0·0935	0·1443	0·1671	0·1621
100	0·0457	0·0558	0·0720	0·0715	0·0762	0·1003	0·1546	0·1792	0·1739
120	0·0516	0·0630	0·0814	0·0807	0·0861	0·1133	0·1748	0·2024	0·1964
140	0·0572	0·0698	0·0902	0·0895	0·0954	0·1255	0·1937	0·2243	0·2176
160	0·0625	0·0763	0·0986	0·0978	0·1043	0·1372	0·2116	0·2452	0·2379
180	0·0676	0·0826	0·1066	0·1058	0·1128	0·1484	0·2291	0·2652	0·2573
200	0·0725	0·0886	0·1144	0·1135	0·1210	0·1592	0·2457	0·2845	0·2760
225	0·0784	0·0958	0·1237	0·1228	0·1310	0·1722	0·2658	0·3077	0·2986
250	0·0841	0·1028	0·1327	0·1317	0·1404	0·1848	0·2851	0·3301	0·3203
275	0·0897	0·1095	0·1414	0·1404	0·1497	0·1969	0·3036	0·3518	0·3413
300	0·0950	0·1161	0·1498	0·1487	0·1586	0·2086	0·3220	0·3728	0·3617

A FRENCH WATER WORKS.

The works for supplying the plain of Lannemezan, at the foot of the Pyrenees, and the numerous villages diverging from it, with water from the River Neste, consist of a canal starting from the river at Sarrancolin, and capable of discharging 280 cubic feet of water per second at the plain, from whence branch drains convey the water to each valley, and also of reservoirs for feeding the canal during the low stage of the river. The canal and the branch drains have been finished, and supply water from the Neste to the parched valleys, with great benefit to the inhabitants; and the Oredon reservoir is the first of the series which has been made, containing 9,508,000 cubic yards of water, out of the proposed total reservoir capacity of 30,085,000 cubic yards. It has been proposed to increase the capacity of the reservoir to 22,236,000 cubic yards, by raising the existing dam 62 ft. The lake of Oredon, which drains into the Neste, a tributary of the Garonne, is in a granitic region, and has an area of 59 acres. It is fed by the drainage from other lakes and some glaciers, and has been converted into a reservoir by a dam across its outlet, which enables its water level to be raised 55¾ ft., and a cutting formed through its outlet enables its original water level to be lowered 23 ft. The 11 cast iron discharge pipes, 1 ft. in diameter, are laid in this cutting in two horizontal rows, and incased in a mass of Portland cement concrete, 26¼ ft. thick and 16¼ ft. high. The dam consists of an embankment, protected on its upper slope by a layer of concrete preserved from frost by dry stone pitching 3¼ ft. thick. The site of the dam was stripped bare to the rock, and all loose pieces of rock were removed. The embankment was tipped from wagons running on rails from the place of excavation; it was consolidated by means of a stream of water, discharging about 3½ gals. per second from a wooden pipe, 2½ feet below the rails, with its outlet at the point where each wagon tipped its load, the pipe being lengthened as the embankment progressed. When two or three wagon loads had been tipped, the water was admitted into the pipe, whose orifice was buried in 4 to 6½ cubic yards of earth; and the water, after penetrating the mass and rendering it pasty, found a vent, and washed earth, sand, and stones toward the base of the bank. The current was directed in various directions successively by men with iron hooks, and the water, flowing away to right or left in the trench, only carried on light soil and fine sand in suspension. The water soon drained from the mass, and left an absolutely incompressible embankment. The surface of the upper slope was then coated with a bed of concrete, 8 in. thick, upon which a layer of rubble stone, 1 ft. thick, was placed, to serve as a drain for preventing any water penetrating the outer layer of concrete from reaching the bank; and the water reaching this drain passes into a collecting culvert built at the base of the rubble drain, through which the water flows to the discharging pipes. The protecting layer of concrete, laid on the rubble drain, was coated on its outer surface with a ⅜ in. coat of bitumen, composed of one part of mineral tar, one and a third of powdered Theil lime, and four parts of fine baked sand, and to form a water tight covering. This coat, though very solid and water tight at first, became less so after some lapse of time, and was therefore coated with a coat of nine parts of tar and eight parts of powdered lime laid on hot. The surplus water of the reservoir flows over a waste weir of 131 ft. long, the stream in flood time, with a full reservoir, reaching a height of 3¼ feet over the sill. The proposal to increase the storage by raising the dam was deemed too hazardous; but the only other way of obtaining the desired reservoir capacity would necessitate raising the water level of same lake 36 ft. and 40 ft. by dams as large as the Oredon dam, without the possibility of making an equally solid bank, through lack of suitable material.

PETROLEUM LAUNCH ZEPHYR.

We illustrate opposite one of four new type launches constructed by Messrs. Yarrow & Company, London, which use petroleum spirit vapor instead of steam as a working fluid. Pleasure boats are extensively used in the United States which use naphtha vapor instead of steam; but the details of construction are different from those adopted by Messrs. Yarrow.

This engine is the invention of Mr. Yarrow, of Poplar, and has been fitted to four launches of various types for experimental use. The trials have extended over several months, and the success which has attended them is such that the experimental stage, as far as small powers are concerned, may be said to be passed, and the new engine is available for general use. It will be seen that the whole of the best space in this boat is available for the accommodation of passengers or a crew. The boat is 36 ft. long and 6 ft. beam, but it weighs complete only about one ton. The space taken up by the boiler and machinery in the stern sheets is very small. The engine may be of any type, and is similar in all respects to a steam engine. In one of Mr. Yarrow's launches there is a single cylinder

inverted vertical engine; in another, a three cylinder Willan's engine.

The working fluid is the vapor generated from petroleum spirit. The boiler consists of about 30 ft. of 1 in. copper tube worked into a double spiral coil, one of the coils being right and the other left handed. The coils are covered by a sheet iron case terminating above in a chimney. The petroleum spirit is forced by a feed pump into the coil, evaporated, and the resulting vapor or petroleum steam is used in the engine precisely like steam. The exhaust vapor passes into two copper pipes lying along the garboard strakes of the hull. These terminate in a small, strong tank in the bows of the boat, which is the equivalent of a hot well, and from which, by another pipe, the spirit condensed in the two submerged tubes is led back to the feed pump.

The entire arrangement is so simple and obvious that it will be understood without further description. The furnace is supplied, not with petroleum spirit, but with the ordinary safe oil used in so-called paraffin lamps. This paraffin oil, as we shall term it for the sake of distinction, is carried in a small circular tank, the top of which may be seen in our engraving just in front of the engine.

This tank is quite air tight, and is fitted with a small hand pump, by which air may be forced in on top of the petroleum in the tank. The pressure thus set up forces the paraffin out of a very ingenious sprayer, the paraffin being first highly heated and gasefied; the flame thus produced is as smokeless as that of a Bunsen burner, and plays on the copper coils containing the petroleum spirit, which, as we have said, is converted into vapor and drives the engine. The working pressure is about 60 lb. above the atmosphere.

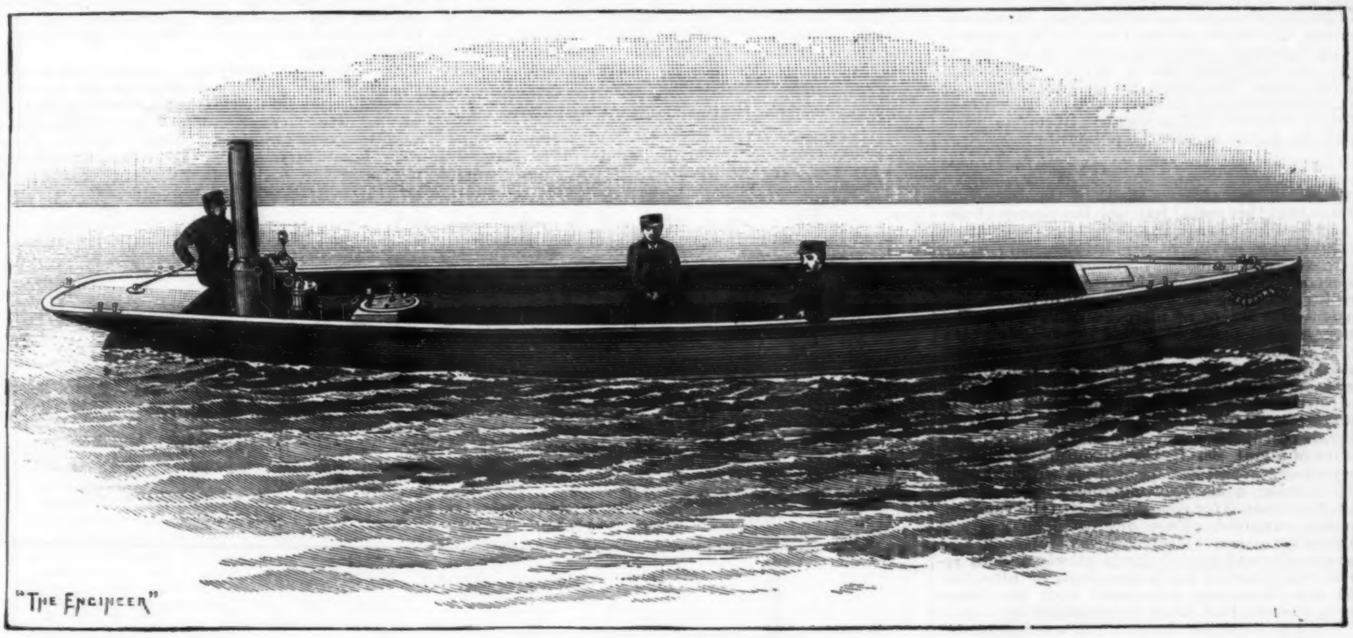
Not the least advantage about the system is that steam can be got up in about five minutes. No coal is carried to make dirt. There are no ashes, or cinders, or smuts to fall about. The boiler once started requires no further attention, so that one man can steer and take charge of the engine. For pleasure boats it far excels anything that has yet been brought before the renew the supply in the tank, as it would readily take fire and burn the boat. But inasmuch as the same spirit is used over and over again for long periods, and the whole quantity carried for the use of a 5 horse engine does not exceed some two or three gallons, this can scarcely be regarded as a risk worth taking into account.

We may now turn to the question of economy, and the results actually obtained by Mr. Yarrow are very curious and interesting. It is laid down by all writers on thermodynamics that the efficiency of a heat engine is entirely independent of the nature of the fluid or other working substance, and is measured solely by the well known formula $E = \frac{T-t}{T}$, where E is the efficiency of the engine, T the absolute temperature at which it receives the working fluid, and t the absolute temperature at which it rejects it.

This is no doubt true when we deal with the working of the fluid, so to speak; but it is open to question if it be true when we have to deal with the making of the fluid as well. Thus it would be true of a hot air engine, for the apparatus does not make the air, but it is not quite satisfactorily proved that it would also be true of a steam engine and boiler combined, in which we have to make the fluid—steam—first and to use it afterward.

In order that it may apply, it is essential that the volumes of a vapor shall vary in the same ratio as their latent heats. Let us, for example, suppose that we have two liquids, one of which we shall call A and the other B. If the latent heat of the vapor of A is one half the latent heat of the vapor of B, then the volume for the same pressure of vapor produced by A will be one half the volume of that produced by B, so that although a pound of coal might evaporate 20 lb. of A and only 10 lb. of B, yet an engine driven by the vapor first of A and then of B would make only the same number of strokes in each case.

The question which presents itself for solution here is, Is this true of petroleum spirit? The only answer



PETROLEUM LAUNCH ZEPHYR.

public in convenience. It possesses all the advantages of electricity, while the fuel used can be bought at any oil shop.

Two very important questions have, however, to be considered. Is the new motor safe? Is it economical, seeing that paraffin oil at 7d. a gallon is a very much more expensive commodity than coal? We shall deal first with the question of safety.

Rock oil is an excessively complex hydrocarbon. It is possible to distill from almost any sample as many as twenty products, each with a different specific gravity and flashing point. Petroleum spirit may be said to stand midway between the highly volatile benzoles and the safe paraffins. Its vapor is, however, of course very inflammable and explosive if mixed with a sufficient quantity of air.

In Mr. Yarrow's launch, however, the spirit is hermetically sealed up in the boiler and condenser tubes. The only places where leakages can take place are at the stuffing boxes. These are fitted with lantern brasses; from each lantern a small tube is led to the condenser, so that leakage into the atmosphere cannot well take place. Even if it did, however, no evil consequences could ensue in an open launch, as the vapor would be too largely diluted to burn.

As a matter of fact, in the experimental shed fitted up in the first instance by Mr. Yarrow, leakages used to take place to such an extent that those in the room could scarcely breathe; but naked gas jets were burning all the time, and no approach to an explosion ever occurred. Whether petroleum spirit could be used in a closed engine room with safety must remain a matter of opinion. We believe that it could. But this is quite beside the question, because there is nothing in common between an open boat and a closed stokehole.

As to the vapor unmixed with air exploding if ignited, that is a physical impossibility. It could no more explode, or even burn, without air than coal gas can. Consequently, if one of the boiler coils were to be split by excessive pressure, the spirit vapor as it rushed out would take fire and flare up the chimney; but the chances of a true explosion resulting are about as remote as would be the case if water were used.

The principal precaution necessary is to take care that none of the spirit is spilled when it is necessary to we can give is that very little is known on the subject, and that Mr. Yarrow's direct experiments go to show that it is not true. In the first place, it is difficult to say what the precise composition of petroleum spirit is; but assuming it to be very nearly the same as benzine, its latent heat is about one-fifth of that of steam; its boiling point is, however, much lower than that of water; at 274 deg. Fah. it has a pressure of about 50 lb. on the square inch above the atmosphere, that of steam of the same temperature being 30 lb.

According to the text books, its vapor volume would be about one-fifth that of steam, or possibly less. The direct experiments, however, made by Mr. Yarrow do not confirm this view. Thus it would appear that the latent heat is much less than one-fifth, for by repeated experiments it has been ascertained that a given weight of fuel—coal gas—will evaporate in an open vessel, under atmospheric pressure, nine times as much petroleum spirit as water. There are corrections to be made, possibly, but the figures cannot be very far from the truth.

The experimental land engine fitted up by Mr. Yarrow has a small vertical boiler traversed by coils of copper pipe. This engine is provided with duplicate sets of condensing apparatus and a small Prony brake, a counter, apparatus for taking diagrams, etc. Steam being raised from water in the boiler, a certain number of revolutions is got by the consumption of a given number of cubic feet of gas burned under the boiler to make steam. Everything else being left unaltered, steam is shut off and petroleum spirit pumped into the copper coils in the hot water in the boiler. The pressure of the steam falls to 30 lb. from 50 lb., that of the petroleum spirit vapor generated in the coil becomes 50 lb., and the engine is then run with it instead of steam, until the same number of cubic feet of gas has been burned.

Dozens of experiments gave the same result. The engine always made at least twice as many revolutions with the spirit as it did with steam. In another experimental engine the spirit was pumped direct into the water in the boiler; the result was about the same—two to one in favor of the spirit; but it was also found that in all cases about twice as much spirit had to be vaporized per minute as water, that is to say, twice as large a feed pump was needed with the spirit as would suffice with the water.

The most crucial test is, however, that supplied by the Zephyr launches to which we have referred. These engines can be worked with water or petroleum spirit; with the latter they indicate about 4 to 5 horse power, with water about 1 or 1½ horse power, the consumption of paraffin oil as fuel being the same in both cases. —*The Engineer.*

[American Chemical Journal.]

ON THE COMBUSTION OF WEIGHED QUANTITIES OF HYDROGEN, AND THE ATOMIC WEIGHT OF OXYGEN.

By E. H. Keiser.

The atomic weight of oxygen is the foundation upon which the entire system of atomic weights rests. It is unquestionably one of the most important constants in chemical science. At the present time the opinions of chemists differ as to its most probable value. While many accept 15·96 as the mean result of all the more trustworthy determinations, others are inclined to believe that the whole number 16 approaches nearer to the truth. Both numbers lie between the maximum and minimum values that have been obtained by the best methods heretofore employed in determining this constant. As all the other atomic weights, with few exceptions, depend upon that of oxygen, it follows that two values may be obtained for each element accordingly as one or the other of these numbers is made the basis of the calculation. As a result of this, all the atomic weights are uncertain to the extent of about one quarter per cent. of their values. It is very desirable for this reason, as well as for others of a more speculative nature—as, for example, the question of the validity of Prout's hypothesis—that the atomic weight of oxygen should be redetermined with the very greatest care.

In a preliminary paper* I called attention to a new method of determining this atomic weight, by means of which, it seemed to me, more accurate results could be obtained than by the older methods. Briefly stated, it consists in burning weighed quantities of hydrogen by passing the gas over heated copper oxide, and weighing the water formed. From the weight of water obtained by the combustion of a known weight of hydrogen, the atomic weight of oxygen may be readily calculated.

It is evident that the accuracy of the results obtained by this method must depend to a large extent upon the purity of the hydrogen that is used and upon the correctness with which it is weighed. It is, however, extremely difficult to weigh accurately any considerable quantity of hydrogen in the gaseous state. If Regnault's method of compensated glass globes be used, it would require very large and heavy vessels to weigh comparatively small quantities of hydrogen, and in weighing such large globes errors may arise from many different sources. Lord Rayleigh† has recently pointed out a source of error in this method which appears to have been overlooked by all who had previously used it. He has shown that the volume of a glass globe is larger when it is full than when it is empty, and that the weight of the gas contained in it is not equal to the difference in weight of the full and empty globe.

In order to be able to weigh hydrogen accurately, I have taken advantage of the beautiful discovery made by Thomas Graham in the year 1866. Metallic palladium, as he has shown, has the power at ordinary temperatures of occluding many hundred times its own volume of hydrogen gas. The palladium hydrogen which is thus formed is stable at ordinary temperatures, and the metal retains the hydrogen even in a vacuum. If, however, the temperature be raised above 100°, then the gas will be expelled in a slow and regular current. Under atmospheric pressure nearly all of the hydrogen can be driven out at temperatures below 200°. By inclosing a quantity of metallic palladium in a glass vessel from which the air has been removed, and saturating it with pure hydrogen, a large volume of the gas may be condensed into a small space. If now the temperature be raised gradually, the gas will be driven out slowly and regularly. If the vessel be weighed before and after the heating, the loss in weight will equal the weight of hydrogen that has been ex

* Ber. d. chem. Ges. 20, 2323. † Chem. News, 57, 73.

pelled. It is possible, therefore, with an apparatus of small dimensions to weigh comparatively large volumes of hydrogen. Preliminary experiments showed that 100 grammes of palladium foil will readily absorb from 0·6 to 0·7 gramme of hydrogen, and that with an apparatus having a volume of about 150 c.c. and weighing 180 grammes, it is possible to weigh, with great accuracy, an amount of hydrogen which in the gaseous state would occupy a volume of from 7 to 8 liters. A glass globe that could hold the same quantity of gas would be much heavier than the tube containing the palladium; and such a globe, owing to its much greater volume, could not be weighed with nearly the same degree of accuracy.

There is, however, another and no less important advantage gained in weighing hydrogen in the condition of palladium hydrogen. It is necessary that the hydrogen which is weighed and burnt for the purpose of determining the atomic weight of oxygen should be absolutely pure. The greatest difficulty connected with the preparation of pure hydrogen is to get rid of all traces of air. Other impurities may be avoided by starting with chemically pure materials for the preparation of the gas, and by using appropriate absorbing and drying reagents for purifying it. If air is present, the oxygen of the air may be removed by passing the gas over heated copper. Water will be formed, and this may be absorbed by means of phosphorus pentoxide. But there is no way of removing the nitrogen. Palladium, however, has not the power of absorbing nitrogen. If the hydrogen used for saturating the palladium contains nitrogen, the hydrogen will be occluded, the nitrogen will remain unacted upon; and, after the palladium has been saturated, the nitrogen may be removed from the palladium tube by means of an air pump.

Thomas Graham,* who first studied the behavior of palladium toward gases, found that hydrogen was the only constituent of illuminating gas that possessed the power of penetrating palladium foil. Wohler† has shown that palladium cannot absorb ethylene, and that at high temperatures it decomposes hydrocarbons into carbon and hydrogen. Wilm‡ has also observed that at high temperatures palladium can decompose hydrocarbons, and he has shown that the hydrogen is absorbed by the metal, while the carbon is left on its surface in an extremely finely divided condition. Hempel§ has found that from a gas mixture containing hydrogen, marsh gas, and nitrogen, the hydrogen may be completely absorbed and separated from the other constituents by means of metallic palladium.

PRELIMINARY EXPERIMENTS.

While it thus appears from a study of the literature of palladium that this metal has not the power of absorbing nitrogen or marsh gas, ethylene, and other hydrocarbons, it, nevertheless, seemed necessary to determine by careful preliminary experiments whether, under the conditions under which the palladium was to be used for occluding hydrogen, it might not be able to take up minute traces of nitrogen or oxygen. For this purpose several pieces of palladium foil, weighing together 140 grammes, after being carefully cleaned and rolled into the shape of a cylinder, were placed in a wide glass tube which was closed at one end. The open end was drawn down to a small diameter and fused to a three-way glass stop cock. The tube was exhausted with a Geissler air pump and the metal heated to a temperature of about 400° in the vacuum. The glass tube was protected from the flame by a wrought iron trough containing a layer of magnesia. After the metal had been heated for some minutes in the vacuum, the lamp was removed. Pure dry nitrogen gas was then admitted by means of the three-way stop cock, and the metal was allowed to cool down slowly and to remain for several hours in an atmosphere of nitrogen. The tube was thereupon exhausted with the pump and, after a vacuum had been obtained, it was again heated. Not the minutest trace of gas was given off. If only a small fraction of a cubic centimeter of nitrogen had been driven out of the palladium, it would have been detected, because the pump was kept in constant operation. The experiment was repeated several times, but the result was always the same. In one experiment the palladium tube was exhausted and weighed. It was then heated in the vacuum and treated with nitrogen as above described. After being again exhausted, the weight was found to be the same as before. It appears, therefore, that under these conditions palladium has not the power of absorbing nitrogen; but these are the conditions that were found to be the most favorable for the occlusion of hydrogen. After the metal had been heated in a vacuum, it was allowed to cool in an atmosphere of hydrogen. The gas was absorbed in large quantities. When perfectly cold, the tube was exhausted and weighed. It was found to be nearly a gramme heavier than it was before the hydrogen had been occluded. The hydrogen was held so firmly by the palladium that, when the tube was exhausted with the air pump, the palladium hydrogen showed but a very slight tension. On warming it, however, the gas was given off in large quantities. Other experiments made with oxygen showed that this gas also, under the conditions described above, is not absorbed by palladium.

Experiments were now made for the purpose of determining what the effect would be of treating palladium with hydrogen containing a small percentage of air. The metal was heated in a vacuum and then allowed to cool in an atmosphere of hydrogen containing air. The hydrogen was rapidly absorbed, but at the same time a minute quantity of moisture was deposited on the interior surface of the tube. When no more gas was absorbed, the palladium tube was connected with a weighed phosphorus pentoxide U tube and heated. As the gas escaped from the palladium tube, the film of moisture gradually disappeared. The U tube was weighed again after the hydrogen in it had been displaced by air. It was found to have increased in weight, thus showing that when palladium is treated with hydrogen containing air, the oxygen is converted into water. The idea suggested itself that perhaps hydrogen dioxide might also be formed, and that the palladium hydrogen in the presence of nitrogen might cause the formation of ammonia. The palladium was therefore treated again with hydrogen containing air, and after the metal had been saturated the palladium tube was connected with a Geissler potash bulb containing Nessler's solution. The gas was thereupon driven out of the palladium tube by heating, and although more than six liters of hydrogen were passed through the Nessler's solution, not the faintest reaction for ammonia was obtained. The experiment was repeated, but in this case, instead of using Nessler's reagent, the gas from the palladium tube was led through a solution of potassium iodide and starch paste to which a small quantity of ferrous sulphate had been added. No reaction for hydrogen dioxide was obtained.

Another experiment was made for the purpose of determining whether palladium itself is not volatilized when palladium hydrogen is decomposed. A quantity of palladium foil was carefully weighed and then saturated with hydrogen. The hydrogen was then completely removed by heating in the presence of air. On weighing the foil again, its weight was found to be unchanged.

The conclusions drawn from the results of these preliminary experiments are as follows: Palladium at temperatures below 400° cannot occlude oxygen or nitrogen. If palladium be treated with hydrogen containing a trace of nitrogen, the hydrogen will be occluded, but the nitrogen will remain unabsorbed, and it may be removed from the vessel containing the palladium hydrogen by means of an air pump. If the tube containing the palladium hydrogen be heated, pure hydrogen will be expelled, and the weight of the gas thus driven out may be determined from the loss in weight of the palladium tube. If palladium be treated with hydrogen containing traces of air, the hydrogen will be occluded, the nitrogen will remain unabsorbed, but the oxygen will be converted into water. By means of an air pump the nitrogen and a portion of the water may be removed from the tube containing the palladium. On heating the tube, the hydrogen which is driven out will carry with it traces of moisture. The weight of the hydrogen and moisture thus expelled may be determined from the loss in weight of the palladium tube, and the amount of moisture present in the hydrogen may be determined by passing the gas through a weighed phosphorus pentoxide U tube. Lastly, palladium itself is not volatilized when palladium hydrogen is decomposed.

APPARATUS FOR PREPARING AND WEIGHING THE HYDROGEN.

The construction of the palladium tube that was used for weighing the hydrogen in the atomic weight determinations is shown in Fig. 1. The expanded portion, *a*, contained 140 grammes of palladium foil that had previously been thoroughly cleaned, and which, before being placed in the tube, had been heated to a bright red heat in a vacuum. The three-way glass stop cock, *b*, was fused to *a*, and its construction will be readily understood from the cross section drawing, *b'*. The end, *c*, was ground to fit accurately into the phosphorus pentoxide tube, *d*, shown in Fig. 3. The diameter of *a* was 3 cm. and its length 14 cm. The total length of the tube, including the stop cock, was 26 cm.; its weight, including that of the palladium, was 204·5 grammes. The first six determinations were made with a somewhat smaller tube, which contained only 100 grammes of palladium and weighed 160 grammes.

The hydrogen that was used for saturating the metal was prepared by the action of pure dilute sulphuric acid upon chemically pure zinc, free from arsenic. The apparatus for generating and purifying the gas is shown in Fig. 2. The zinc was placed in *e*, and it was acted upon by the dilute sulphuric acid contained in *f*. The vessel, *f*, was supported by a shelf, and was connected with *e* by means of glass tubing, as shown in the figure. After leaving the generating apparatus, the hydrogen passed through four wash bottles. The first one contained a solution of lead hydroxide in concentrated caustic potash; the second one, a concentrated solution of potassium permanganate, acidulated with dilute sulphuric acid; the third one, an alkaline solution of potassium permanganate; and the fourth one, pure concentrated sulphuric acid. To the fourth wash bottle was connected the combustion tube, *g*, which contained metallic copper. The copper was obtained by the reduction of the chemically pure oxide in a current of hydrogen. A small gas furnace supported the combustion tube, and while the gas was being generated the tube was kept at a bright red heat. After having passed over the heated copper, the gas was conducted through the U tube, *h*, which was filled with phosphorus pentoxide. The joints of the apparatus were made of thick walled rubber tubing; they were all wired securely and coated with varnish.

The method of charging the palladium with hydrogen was conducted as follows: The palladium tube, resting upon a trough of sheet iron and protected from contact with the iron by a layer of magnesia, was connected with a Geissler air pump and exhausted.

After the palladium had been heated to a temperature of about 250° for fifteen minutes in the vacuum, the stop cock, *b*, was closed, and, while the tube was still warm, the end, *c*, was connected with the U tube, *h*, as shown in Fig. 2. Meanwhile all the air in the hydrogen generating apparatus and the wash bottles had been expelled, as the evolution of gas was begun more than one half hour before the palladium tube was attached. For several minutes more the hydrogen was allowed to escape from the downward branch of the stop cock, to which a straight glass tube dipping in mercury was attached, to insure that all the air had been displaced in the tube connecting the palladium vessel with the U tube, *h*. The stop cock was then turned carefully so as to allow a slow stream of hydrogen to enter the warm palladium tube. Under these circumstances the metal absorbs the hydrogen so rapidly that it is necessary to open the stop cock very cautiously, otherwise the gas will pass too rapidly through the wash bottles.

While the hydrogen is being absorbed the metal cools down very slowly, because considerable heat is evolved in the formation of palladium hydrogen. When the absorption of gas had become very slow—and from two to two and a half hours sufficed for saturating 140 grammes of palladium—the stop cock was closed and, after being again attached to the Geissler pump, the tube was exhausted. By this means nitrogen, if it should have been present in the hydrogen used for saturating the palladium, was removed. Palladium hydrogen gives off hydrogen very slowly in a vacuum, so that, if the pump be kept in operation for some time, all traces of nitrogen in the palladium tube and in the pump itself may be completely carried out by means of this slow evolution of gas. After the removal of the nitrogen the tube was closed and disconnected from the pump. It was then thoroughly cleaned and placed in the balance room.

A short beam analytical balance, made by Becker Brothers, New York, was used for all the weighings. It could carry safely 225 grammes in each scale pan, and was adjusted so that a load of one milligramme caused a deflection of twelve divisions of the ivory scale. All weighings were made by the method of vibrations. In weighing the palladium tube and the tubes used for condensing and absorbing the water, each tube was compensated by a similar one, of the same external volume, constructed of the same material, and having nearly the same weight. The weights were also made by Becker Brothers; the smaller ones were of platinum, the larger ones of brass. One of the ten-gramme weights was selected as the standard, and the relative values of all the others were determined by the well known method of adjustment. All atomic weight determinations were made on days when the weather was clear and dry; and, as a combustion including the weighings could be made in four hours, the barometer, temperature of balance room, and the humidity of the air remained practically constant during each determination.

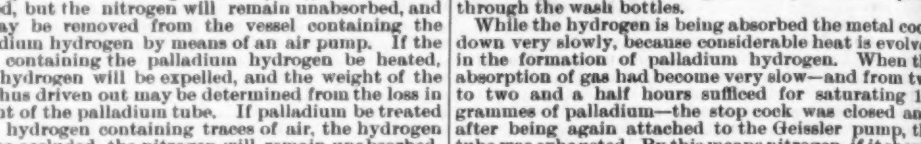


Fig. 1

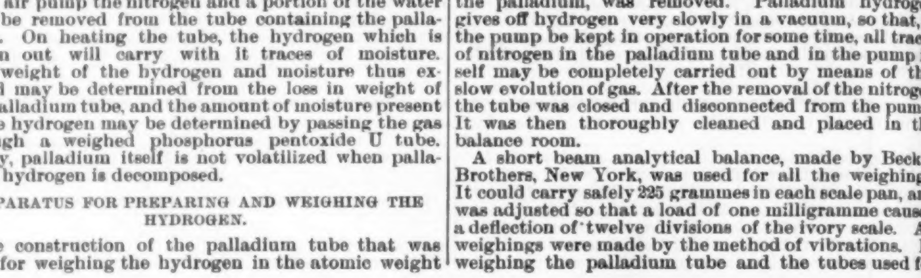


Fig. 2

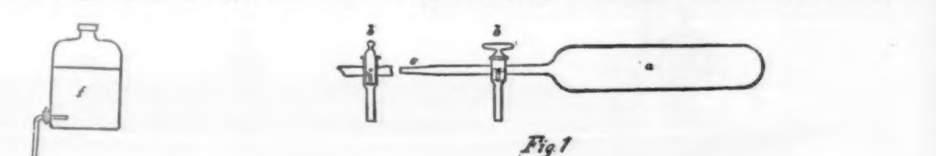


Fig. 3

METHOD OF BURNING THE HYDROGEN.

The arrangement of the apparatus that was used for burning the hydrogen is shown in Fig. 3. The palladium tube was connected by means of a ground glass joint with the weighed phosphorus pentoxide tube, *d*. The latter tube served to determine the amount of moisture in the hydrogen that was expelled from the palladium tube. The tube, *d*, was connected by means of another ground glass joint with the combustion tube, *n*, which contained copper oxide. For the purpose of obtaining pure copper oxide, the chemically pure granular oxide of commerce was reduced in a current of pure hydrogen, and the metallic copper thus obtained was heated to a bright red heat in a vacuum. All volatile matter having been removed in this way, the copper was oxidized with pure oxygen. In each determination the reduced copper was again oxidized to copper oxide, so that the condition of the combustion tube was the same at the beginning and end of the combustion. The copper oxide that was used in the determinations recorded below had been repeatedly reduced and oxidized in preliminary determinations. The combustion tube was 90 cm. in length and had an internal diameter of 15 mm. It was filled to within 10

* Ann. Chem. (Liebig) Supp. Band 5, 61.
† Ber. d. chem. Ges. 14, 874.
‡ Ann. Chem. (Liebig) 184, 129.
§ Ber. d. chem. Ges. 12, 636.

cm. of the open end, and it contained so much copper oxide that there was never more than one half of it reduced in any determination. The object of this large excess was to insure the complete combustion of the hydrogen. The water formed by the combustion of the hydrogen was condensed in the bulb apparatus, *p*, and the U tube, *r*. When not connected with the combustion tube, *p* was closed by means of ground glass plugs. A tightly fitting rubber stopper was used to connect the bulb apparatus with the combustion tube. During the combustion the bulbs were kept cool by being surrounded with cold water placed in a glass dish. The U tubes, *r* and *s*, contained phosphorus pentoxide, and *s* served to protect *r* in case air should be drawn backward into the combustion tube. To the downward branch of the stop cock of the palladium tube was attached the three-way glass stop cock, *m*, by means of which either oxygen or nitrogen could be passed through the apparatus. The oxygen before entering was conducted through concentrated sulphuric acid, concentrated caustic potash, and over phosphorus pentoxide. The nitrogen was purified by passing through concentrated sulphuric acid, concentrated caustic potash, over red hot copper to remove the oxygen, and then over phosphorus pentoxide.

The combustion of the hydrogen was conducted in the following manner: In the first place, the copper oxide was heated to a bright red heat in a current of dry air, so as to remove hygroscopic moisture. The U tube, *d*, the palladium tube, and the tubes, *p* and *r*, after having been carefully weighed, were connected as shown in Fig. 3. The tube, *s*, and the stop cock, *m*, were then attached, and a stream of nitrogen was allowed to pass through the apparatus for from 20 to 30 minutes to expel the air, thus avoiding the possibility of an explosion when the hydrogen was admitted. The palladium tube was thereupon warmed gently, and, after its temperature had risen to a little above 100°, the stop cock, *b*, was turned slowly so as to cut off the current of nitrogen and to allow a slow stream of hydrogen to pass through *d* into the copper oxide tube. In warming the palladium tube the flame never came in contact with the glass. The tube was always supported by an iron trough, and the glass was protected from contact with the iron by a layer of magnesia. The rate at which the gas was expelled and burnt could be easily regulated by raising or lowering the temperature of the palladium tube. After the greater quantity of hydrogen had been burnt and the current of gas had become very slow, the stop cock, *b*, was turned to its original position, thus closing the palladium vessel and readmitting the stream of nitrogen. The palladium tube was then allowed to cool; in so doing the metal reabsorbs the gaseous hydrogen that is present in the tube, and at the end of the operation the pressure in the interior of the tube is the same as at the beginning. After the nitrogen had carried all of the hydrogen into the combustion tube, oxygen was admitted through *m*, and the reduced copper was converted into copper oxide. The oxygen was then displaced by a stream of dry air, and the copper oxide was allowed to cool.* The tubes were then disconnected and, after being cleaned, were taken to the balance room. They were allowed to stand a sufficient length of time to acquire the temperature of the room, and were then weighed.

The weight of water formed was determined from the increase in weight of *p* and *r*. To the weight of liquid water in *p* was added the weight of air which it displaced, thus its weight in vacuo was obtained. The weight of the tube, *d*, remained the same as at the beginning of the combustion, provided the hydrogen that had been used for saturating the palladium was free from oxygen. In this case the loss in weight of the palladium tube gave the weight of hydrogen that had been burnt. If, however, a small quantity of oxygen was present in the hydrogen used for charging the palladium, then the gas that was expelled from the tube contained a trace of moisture, and, in this case, the increase in weight of *d* had to be deducted from the apparent weight of hydrogen. In all carefully conducted atomic weight determinations, the increase in weight of *d* was never found to be more than a fraction of a milligramme.

ATOMIC WEIGHT OF OXYGEN.

The following results have been obtained by this method:

No. of Experiment.	Wt. of H burnt. Grammes.	Wt. of Water obtained. Grammes.	Atomic Wt. of Oxygen.
1	0·34145	3·06338	15·943
2	0·68394	6·14000	15·955
3	0·65529	5·88200	15·952
4	0·65295	5·86206	15·954
5	0·66664	5·98116	15·944
6	0·66647	5 98341	15·955
7	0·57967	5·20493	15·958
8	0·66254	5·94758	15·952
9	0·87770	7·86775	15·950
10	0·77215	6·93036	15·951
Total	6·55880	58·86263	[15·9492]

From these numbers the ratio of hydrogen to oxygen is found to be: H : O :: 6·55880 : 52·30383, or H : O :: 1 : 7·9746, and the atomic weight of oxygen = 7·9746 × 2 = 15·9492. Maximum value, 15·958; minimum value, 15·943. The result obtained from these determinations appears, in the author's mind, to furnish very strong evidence in favor of the view that the relative atomic weight of oxygen cannot be greater than 15·96, and that its true value is probably a little less than this number.

Several months after the appearance of my preliminary paper, and while this investigation was still in progress, Prof. J. P. Cooke and Mr. T. W. Richards published the results of a redetermination of the atomic weight of oxygen by the same general method which I had proposed. They also have determined the quantities of water formed by the combustion of weighed amounts of hydrogen. But our work differs very much in the methods employed for weighing the hydrogen. Messrs. Cooke and Richards have weighed it in the gaseous state, and have used Regnault's method of weighing gases by means of compensated glass globes. Aside from the difficulties of weighing accurately such large glass globes, owing to air currents, changes of atmospheric condition, etc., and the fact that a comparatively heavy vessel must be used for weighing but a small quantity of hydrogen, this method is open to the objection that all impurities that may be present in the gas, such as traces of nitrogen or air, are weighed as hydrogen. Errors caused by impurities in the hydrogen tend to diminish the atomic weight of oxygen. On the other hand, Lord Rayleigh has pointed out another source of error which tends to increase the atomic weight. As mentioned above, the volume of a glass globe is not the same when it is full and when it is empty, and the difference between the full and empty weighings is less than the true weight of hydrogen.

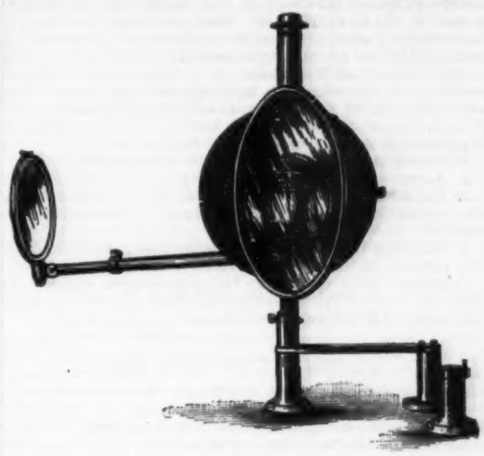
The method which I have employed for obtaining weighed quantities of hydrogen seems to me to be free from these sources of error. By using palladium, a considerably larger quantity of hydrogen may be obtained from a very much smaller and lighter apparatus, consequently the gas can be weighed with greater accuracy. Impurities such as nitrogen and oxygen are eliminated, and as the pressure in the interior of the palladium tube is the same at the beginning and end of the determination, and as the vessel is of small dimensions, there can be no change of volume of the tube. Nevertheless, the value for the atomic weight of oxygen obtained by Messrs. Cooke and Richards agrees very closely with that obtained by this method. Value obtained by Cooke and Richards = 15·953.* Value obtained by the palladium method = 15·949. That our results do not differ more is probably due to the fact that the errors in the method used by Messrs. Cooke and Richards are in opposite directions and tend to neutralize each other.

VERNON HARCOURT'S NEW PHOTOMETER.

The holophotometer has been designed in order to get rid of two difficulties connected with other methods of attaining the same object, viz., to measure the light emitted in every direction by any luminous source. These difficulties are: (1) The movement of the light to be measured or of the standard lamp, neither of which is desirable. (2) The errors caused in the measurement of lamps provided with reflecting fittings, by the assumption that the flame is the zero point from which measurements should be made, whereas, strictly speaking, the principal focus formed by the reflector should be taken as the zero point. Inasmuch, then, as this focus may be several inches away from the flame, and as the length of bar usually employed is 60 inches, it is evident that serious errors may be introduced by the difference between the real and the assumed zero point. To establish the existence of such an error, and to eliminate it, two things are necessary, viz., that readings should be taken with bars of various lengths and that the length of the bar should be very great

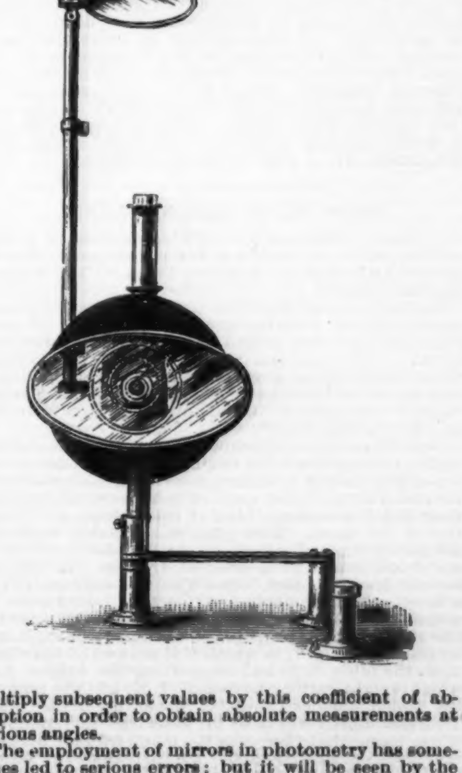
compared with that between the real source of light and the focus formed by the reflector. Both these points are secured by the use of the holophotometer. The instrument is mounted upon a table capable of being moved nearer to or further from a fixed table containing a graduated bar with movable disk (say of the Letheny pattern), and having a standard lamp fixed at the zero of the bar. The lamp to be measured is mounted upon or is in rigid connection with the movable table, and is therefore not moved during a series of readings.

The holophotometer consists of an axis working friction-tight in a collar supported by a vertical pillar. The axis is accurately fixed at the same height, and in a line with the center of the disk. At the end nearest to the disk is placed a large mirror with its center concentric with the axis, but so arranged that the plane of the mirror may be inclined and clamped at any angle to the axis. At the other end of the axis is fixed a telescopic arm carrying a smaller mirror, which is capable of being turned into any required position. The arm being rigidly fixed to the rotating axis of the instrument, to which is also attached the larger mirror,



it follows that the rotatory motions of the mirrors about the axis are identical. The angles of rotation are measured by the indications upon a divided circle attached to the moving axis, which are shown by a pointer fixed to the upright support.

The mirrors are adjusted in such a way that the light from the lamp to be measured falls upon the smaller mirror, thence is reflected on to the larger one, and, finally, along the axial line of the photometer disk. As both mirrors rotate together, it follows that if a horizontal beam is reflected correctly, all other beams will find their way along the axis of the photometer. If, therefore, the arm carrying the small mirror be moved through various angles, it will receive the light emitted from the lamp at those angles, and the light will at every angle be transmitted along the axis of the photometer. The divided circle is made large enough to serve as a complete screen of all direct light, and only the light falling on the small mirror can find its way to the disk. In order that absolute, as well as comparative, tests may be carried out, only one additional measurement need be made. The direct horizontal light is measured without the interposition of the holophotometer (which is mounted so as to be easily moved out of the direct line); then the mirrors are interposed, and a new measurement made. The additional path traveled by the light is allowed for in calculation, and thus the absorption of the mirrors is found once for all for the particular character of light under measurement. It is only necessary afterward to



multiply subsequent values by this coefficient of absorption in order to obtain absolute measurements at various angles.

The employment of mirrors in photometry has sometimes led to serious errors; but it will be seen by the foregoing description that inasmuch as the relative angle of the mirrors is never changed, and as their absorption is easily calculated and allowed for, the only objections to their use have been guarded against and avoided.

In order to eliminate the second source of error men-

* For the purpose of determining whether traces of hydrogen could escape combustion by this method, the following experiment was made: About one half of the copper oxide in the combustion tube was reduced with hydrogen, then a current of carbon dioxide was allowed to enter at *m*, so as to carry all of the hydrogen into the combustion tube. The gases after passing over the copper oxide were conducted through caustic potash, then over phosphorus pentoxide, and again over copper oxide contained in a second combustion tube. To this second combustion tube was attached a weighed phosphorus pentoxide tube. If any hydrogen should have escaped combustion in the first combustion tube, where it was diluted with a large excess of carbon dioxide, it must have accumulated in the caustic potash bulbs. Subsequently, when air was drawn through the apparatus, the hydrogen would have been carried into the second combustion tube in much more concentrated condition than it left the first one. In this tube it would have been burnt, and the phosphorus pentoxide tube would have increased in weight. Although the experiment was tried several times, the weight of the latter tube always remained constant.

* Professor Cooke has recently determined the value of the error caused by the change in volume of the glass globe. He finds the corrected atomic weight of oxygen to be 15·869. This result, it seems to me, is undoubtedly too low. In my preliminary experiments (Ber. d. chem. Ges. 20, 2,323), before the precaution was taken to remove traces of nitrogen by exhausting the tube containing the palladium hydrogen, nearly the same figure was obtained, viz., 15·872.

tioned above, viz., that arising from the formation of a principal focus, it is only necessary to take a series of readings with the table in one position, and then move it to a greater distance and take another series. If a focus is formed at a sufficient distance to produce an appreciable error, it will clearly appear in the difference between the readings at the two distances, and then it is only necessary to wheel the table to such a distance that the discrepancy is inappreciable. In other words, this is equivalent to using a bar of sufficient length to make it practically infinite compared with the distance between the focus and the real source of light.

The instrument has been designed specially for use in lighthouse work, where it becomes of the highest importance to measure accurately the total light given by any lamp, and not only that emitted in any one direction, which may or may not be the maximum.

Preliminary experiments made with the instrument by Mr. Stepney Rawson, at the works of the Woodhouse & Rawson Electric Manufacturing Company, have shown what a valuable instrument it is for the determination of the commercial value of various lamps, as well as for assisting in the many difficult problems of the diffusion and reflection of light. The absorption of the two mirrors used is, as already mentioned, stated to be only 1·8 per cent.; but a series of experiments is to be made upon this point.

We show here three views of the instrument:

1. As shown from behind, showing the divided scale.
2. Looking from the photometer disk, showing how the horizontal light from the lamp is transmitted to the disk.
3. Looking from the photometer disk, showing how the vertical light would be transmitted to the disk.

Inquiries with regard to the instrument should be addressed to the Woodhouse & Rawson Electric Supply Company.—*Electrical Review.*

MOVEMENT OF THE AIR.

At a recent meeting of the Berlin Physical Society, Dr. Lummer gave an abstract of a paper on the movement of air in the atmosphere, which he had recently read before the Academy of Sciences. In solving the problem, he had made use of the principle of mechanical similarities. When the hydrodynamic equation for a given motion is known, it is only necessary to multiply all the factors by n in order to represent the motion in much larger dimensions. Accordingly, if the conditions of the occurrence of air currents, such as take place in the atmosphere, have been experimentally determined in the laboratory for 1 cubic meter of air, and if the atmosphere is assumed to be 8,000 meters high, then the space, time, and moment must be multiplied by 8,000, while on the other hand the internal friction must be taken as being only 1/8000 of that which has been determined by experiment. It follows from this that the internal friction is of very small account; but as against this, the friction of the earth's surface has a considerable influence and cannot be neglected. Supposing a mass of air moving horizontally is considered, then a series of particles of air, which were at the outset vertically each above the other, will finally place themselves along a curve of sines as the result of friction at the earth's surface. Calculation shows that it would require a period of 42,000 years before the motion was reduced to one-half as the result of internal friction. The speaker then considered the atmosphere as made up of rings of air which surround the earth in coincidence with the parallels of latitude; each of these rings of air has its own moment of rotation, which depends on its radius, and is therefore greatest at the equator and least at the poles. If the air which is streaming upward at the equator were to stream down again to the earth in higher latitudes, it would be moving with a velocity far exceeding that of any known storm, even at the latitude of 30°. Since the internal friction of the air is so small that it may be neglected, the speaker proceeded to point out the other factors which have an influence in slowing down the air as it falls. He regards them as being the vortex motions which take place in the atmosphere at the discontinuous surfaces of two masses of air moving with different velocities. These vortex motions cause the adjoining layers of the two masses of air to mix, and thus diminish their velocity. This is the explanation of the calms, trade winds, sub-tropical rains, and other phenomena which occur in the atmosphere.

MEASURING EARTHQUAKES.

On June 1, Professor J. A. Ewing delivered a Friday evening lecture at the Royal Institution upon "Earthquakes and How to Measure Them." Mr. William Crookes presided.

The lecturer said that the students of earthquakes want to know how the ground moves, and in what direction, and what he had to say upon the subject referred to what has been done of late years in Japan, where earthquakes are frequent; in fact, in Tokio they get an earthquake nearly once a week, so that the chair of seismography in the university there is known as "the rocking chair."

One of the earliest attempts to learn something about earthquakes consisted in setting upon end a number of broad and narrow cylinders, something like ninepins; the idea was that when some of these were overthrown, they would give some idea of the violence and direction of the shock. This plan was founded upon the mistake of supposing that an earthquake consisted of one shock instead of a series of tremors. It did not answer, for it was soon found that the columns fell in a most eccentric manner. Of actual instruments to measure earthquakes, Dr. Verbeck in 1876 invented one of the first, the principle of which may be explained by the aid of Fig. 1, in which F F are two of four balls upon the table, R R, and supporting the weight, A B, which weight carries the pencil, E K, and the point of the pencil touches a sheet of paper upon the table. This instrument was tried for some time in Japan, but it was found that there was too much friction between the block, balls, and table; another cause of failure was due to the circumstance that an earthquake usually moves through such small spaces. The common pendulum was tried as an instrument, but found to be open to serious objection, for if the support move rapidly in comparison with the pendulum the latter will remain almost at rest, and if its period of vibration should be the same as that of the pendulum, it will give the latter a great swing. An earthquake consists usually of many hundreds of irregular motions, which in the end set the pendulum swinging in a large arc. The stability of the pendulum can, however, be reduced by lengthening it, so one was tried about 20 ft. long; it gave fairly satisfactory results, but required a special building for its suspension.

The horizontal pendulum seismograph, the principle of which may be explained by Fig. 2, has been compared to a gate swinging upon its vertical hinges, with the hinges made to give as little friction as possible. The leaden weight, A, at the end of the pointed bar, A E, is supported by the upright, B E, and the string, B A. A "gate" of this kind will only act in obedience to motions at right angles to itself, so two of them, placed at right angles to each other, have to be used.

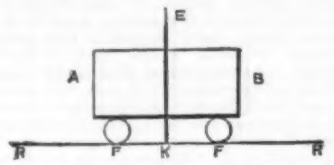


Fig. 1.

They have been employed in Japan, and made to write their record upon a horizontal plate of smoked glass, Fig. 3. This machine measures the horizontal motion of the ground. The earthquake motion is not in a straight line, but in curves, so sometimes one "gate" does the recording and sometimes the other; for instance, an earthquake nearly always begins with small tremors, as at A; some larger ones follow; then when the motion changes, the recording is done at B by the other horizontal pendulum. This apparatus takes no account of vertical motions.

The speaker exhibited an electric seismoscope, made somewhat upon the above principle. It was furnished with two clocks, one of which started the apparatus when the shakings began, and registered the time. It likewise acted as a check upon the accuracy of the

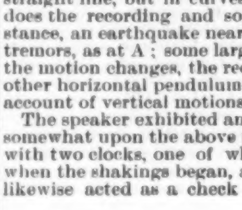


Fig. 2.

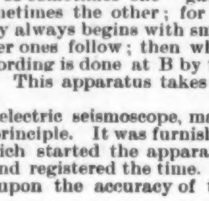


Fig. 3.

driving clock. The two clocks were simultaneously started by electricity.

An earthquake always begins with small vibrations, and of those which follow none stands out remarkably abruptly from the rest. The motion is scarcely a "shock" at all, but a "wobbling" of the ground in every conceivable direction. A movement of the earth of 1¾ in. is the largest yet recorded by the instruments in Japan. Usually the motions are but a small fraction of a millimeter.

The duplex pendulum seismograph is an instrument the principle of which may be explained by the aid of Fig. 4, in which the weight, E, is supported by three wires, B C D, hanging from the block, A; the weight, N, of an inverted pendulum rests upon the support, W, by means of the steel bar, P. The two weights are loosely held together by a kind of ball-and-socket ar-

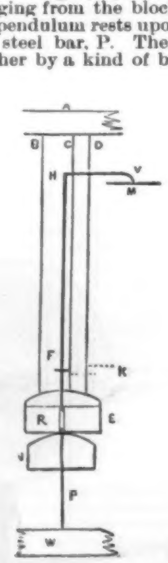


Fig. 4.

rangement at R. At F the rod, H, is supported by two axes at right angles to each other, held by a bar at K; this leaves the rod, H, free to move in any direction; its indicator, V, is hinged to it at H, and the point of the indicator works upon the smoked glass, M. He had recently used this instrument to measure the shaking of the new Tay Bridge in the middle of its longest span, and the maximum vibration while a train was passing over it was less than ⅛ in.; the seismograph gave indications when a train began its course upon the bridge, at a distance of 1½ mile from the instrument. Different well made seismographs agree excellently in their indications. Seismometrical indications of vertical motions can be obtained by means of a spiral spring weighted at the lower end.—*The Engineer.*

THE EARTH AS SEEN FROM THE HEAVENS.

The earth exhibits different aspects that human eyes will never contemplate, that the boldest of travelers, the most fearless of aeronauts, can perceive neither from the summits of mountains nor from the heights of the atmosphere, since, in order to fix one's eyes upon these singular aspects, it is necessary to cross immense spaces through the infiniteness by which our globe is surrounded.

It is only in imagination, upon the swift wings of astronomical science, that we can accomplish this extraordinary voyage. Let us in the first place observe the spectacle that the earth offers to the lunarians or selenites—if such exist—then, leaving the terrestrial domain, let us examine the aspect of our globe as viewed from different planets, successive stages of our odd excursion into the heavens.

Seen from the moon, which gravitates around us at the mean distance of 240,000 miles, the earth appears four times greater in diameter and thirteen times wider in surface; and, consequently, more luminous than our satellite does to us. Immovable in the black depths of celestial space, she soars with majesty, seeming to reign over human destinies, and shows phases analogous to those exhibited by the moon, but in inverse order.

When the sun covers with his rays the terrestrial hemisphere that faces the moon, the latter is new, and the full earth is shining in the sky, while at the moment of the full moon, it is the non-illuminated half of our globe that is turned toward this neighboring world; the earth is then new. To the first lunar quarter corresponds the last terrestrial quarter, and to the first quarter of the earth, the last quarter of the moon.

The lunar day, the period during which our satellite successively presents every portion of her surface to the solar rays, and consequently makes one revolution upon her axis, equals 29 days 12 hours and 44 minutes.

During this long diurnal poriod, the earth offers its first quarter at sunset and its last at sunrise. So the "earthlight" contributes much more to the illumination of the lunar nights than the moonlight does to the illuminating of our nights, and the selenites have truly more reasons for believing that the earth exists for the sole purpose of dissipating the darkness of their nights than we have for considering the moon as created to be the torch of terrestrial nights.

Our planet is afterward visible, amid the stars, and despite the sun's presence, under the form of a large crescent which gradually diminishes in width, until it entirely disappears at the moment of the new earth. The daily rotation of the earth upon its axis forms a very attractive spectacle. Varied spots mark our continents and seas, over which move vast bands of clouds. Two white caps cover the poles. The oceans have a bluish green color and appear darker than the land. The contour of the disk, more luminous than the inner part, is slightly reddish under the influence of atmospheric refraction. Europe and Africa, Asia and the Indian Sea, the Pacific, the two Americas, and the Atlantic defile in turn every twenty-four hours. The earth thus forms a marvelous celestial clock that may be consulted by but a glance under the heavens, and to which the succession of the terrestrial phases adds another base for the measurement of time.

Seen from the center of the visible hemisphere of the moon, the earth hovers always at the zenith. In measure as an advance is made toward the edges of the disk, our globe appears to descend progressively, and, from the circumference of the lunar hemisphere, it is observed to oscillate at the horizon.

Like all the stars of the celestial vault, the sun pursues its apparent course much beyond the earth, and, in its daily motion, passes either above or below our immovable planet, or sometimes even behind her. An eclipse of the sun by the earth then occurs, while an eclipse of the moon is visible to us. As the apparent diameter of the sun is four times less than that of the earth, this sublime phenomenon lasts about two hours when the eclipse is total, and is accompanied with wonderful plays of light, that are caused by the terrestrial atmosphere, and that have the effect of surrounding our globe (which is then dark) with a luminous aureola. It is likewise possible to observe the partial eclipses of the earth which occur when we are spectators of eclipses of the sun.

At times, stars or planets come in conjunction with the earth, or hide behind it, and are projected upon the edge of its disk in consequence of the absorption to which our atmosphere gives rise.

In the course of the long lunar night of 354 hours which forms half of the diurnal period and succeeds daylight, the earth soars majestically in the heavens, undergoing her phases from the first to the last quarter, and, at midnight, shines with an intense light, fourteen times stronger than that of the full moon. With so strong a light do we illuminate that part of our satellite which is dark at this epoch that it becomes visible from here, owing to the reflection of the terrestrial rays from its surface. This reflection of a reflection is styled ashen light.

The earth, an enormous globe of ever varied aspect, suspended at a fixed point of space, therefore presents to the selenites a charming spectacle. The inhabitants of the invisible hemisphere of the moon, where our globe is unknown, have to take a long voyage in order, from the lunar face turned toward us, to contemplate that magnificent star which we call the earth, and which up there must bear names that express all the admiration that she inspires.

Seen from her sisters, the planets, the earth suddenly loses the magnificent aspect that she exhibits in the lunar heaven, and the great diameter that she seems to have, when viewed from our satellite, is reduced to very modest proportions.

The terrestrial globe, so long regarded as composing the entire universe (and how many people labor under such a delusion), is, when seen from these neighboring stations upon the celestial route of infinity, nothing more than a star among the stars.

To Mercury, the nearest planet to the sun, and which gravitates around the latter at a mean distance of 37,000,000 miles, the earth is an external planet, shining with the light of a star of the first magnitude. She sparkles in Mercury's sky as Jupiter does in ours. At the epoch of her opposition with the sun, the earth passes to the meridian at midnight and is in the best period of visibility, with an apparent diameter of 37". After Venus, it is the most brilliant star to the Mercurians, who see our planet gravitate, like it, though the

constellations of the Zodiac. A strong eyesight doubtless permits a slight luminous spot to be seen, now to the left and now to the right of the earth. This little star is the moon.

Seen from Venus, which revolves around the sun at a distance of 68,000,000 miles, the earth exceeds in luster the most brilliant of the stars and offers a perceptible diameter. The same as for Mercury, our globe is an external planet passing to the meridian at midnight when she is in opposition with the sun. The apparent diameter of the earth then rises to 65″, and so its brilliancy is greater than that exhibited by Venus at the epoch of her maximum luminous intensity, and, while this beautiful planet is to us a morning and evening star, the earth to her is a splendid star of night.

The color of the terrestial disk, in becoming modified in consequence of the daily revolution of our globe, which presents maritime and continental surfaces in turn to the solar rays, suffices to demonstrate to the inhabitants of Venus the existence of a daily motion of the earth upon its axis. At the epoch of its greatest angular distances, the terrestrial globe does not present with a full front the hemisphere lighted by the sun, and shows a light phase that renders her form oval.

The moon shines like a white speck, at a distance from our planet sometimes greater than the lunar diameter as seen from here, and her revolution in 28 days around the earth can be followed with the naked eye.

From Mars, which is 145,000,000 miles distant from the sun, the aspect of the earth is analogous to that exhibited to us by the beautiful planet Venus. As its orbit around the sun is interior to the curve described by Mars, it becomes a morning and evening star. The best period of visibility of the earth occurs when it is situated at right angles with the sun, that is to say, at the epoch of its greatest elongation. To the inhabitants of Mars, the earth is then a brilliant star that follows or precedes the sun, and attains an angular diameter of 60″. The smallest optical instrument permits of seeing the different phases offered by our planet, from a full luminous disk to a thin crescent, and its entire disappearance in the vicinity of the star of day.

Perhaps, when the earth rises on the Martial horizon illuminated by the first light of Aurora, or when it descends, after the sun, bathed in the last fires of twilight, the inhabitants of this neighboring planet admire it as an abode of peace and happiness. How great would they find their mistake to be were they able to come hither!

The passage of the earth and its satellite before the sun constitutes a rare and interesting observation for the astronomers of Mars. Thus, on the 12th of November, 1879, at 2 o'clock P. M., they could have perceived a small black point indenting the solar disk and taking six minutes to enter it wholly. Toward 4 h. 15 m. appeared a second and much larger spot, which took 21 minutes to enter the sun. At 10 h. 15 m., the first of these minute disks made its exit on the opposite side, and near midnight the second also detached itself from the sun. These two stars were the earth and moon. Their former passage occurred in the year 1800, and the next one will be seen from Mars in 1905. . . .

The earth is surprisingly visible in the heavens of the planets that we have thus far mentioned, but when, reaching colossal Jupiter, which is at a mean distance of 495,000,000 miles from the sun, we cast a glance behind, our little globe no longer soars amid the celestial spaces. A neighbor of the sun, almost eclipsed by its blinding rays, the earth oscillates but 12° to the east and west of the star of day. Feeble morning and evening star, she precedes its rising and follows its setting.

If the inhabitants of Jupiter possess sight like ours, they can scarcely see the earth except by artificial means.

It is especially at the periods of our passages annually before the sun (five times smaller there than here) that the Jovian astronomers can discover our globe, under the aspect of a small black point moving over the solar disk.

To Saturn, the earth is separated from the sun by but 6°, and passes over it every fifteen days. To Uranus she is separated by 3°, and to Neptune by but 2°.

Immersed in a luminous fascicle of solar rays, our globe is entirely invisible to these latter planets of the system to which it belongs. The earth *is unknown* to these worlds, which are relatively near and are connected, like it, with the destinies of the sun; and the existence upon it of the people that inhabit it, of that intelligent race which believes itself to be alone in the universe, is suspected by no one. To these planets neighboring our own, we do not exist. Seen from the nearest of the stars, the enormous sun that illuminates us is itself no more than a little point, no more than a minute star, wandering in the infinite labyrinth of the worlds.—*J. Leotard, in La Science Illustre.*

[Continued from SUPPLEMENT, No. 658, page 10515.]

GEOLOGY.

By ARCHIBALD GEIKIE, LL.D., F.R.S.

IV. How the Remains of Plants and Animals come to be found in Sedimentary Rocks.

ALTHOUGH sedimentary rocks consist of such materials as gravel, sand, or mud, they often contain other things quite as interesting and important. For example, here are two additi nal pieces of shale (Figs. 12 and 13), in which you will see certain objects very different from the ordinary sediment of which the stone is made. Let us first satisfy ourselves as to what these objects are, and then as to how they came to be embedded in the stone.

We begin with the specimen which is drawn in Fig. 12. In the stone itself you would recognize merely a fragment of common shale, formed of the same materials and arranged in the same stratified way as in your former specimen of that rock.

But what is this black object lying on the upper surface of the stone? You see at once that is has the form of a plant and resembles some of the fern tribe. Examine it more closely, and, tracing the delicate veining of the fronds, you cannot doubt that, although no longer soft and green, it was once a living fern. It has been changed into a black substance which, when you look carefully at it, proves to be a kind of coal. Little fragments and layers of the same black coaly substance may occur throughout the piece of shale. If you scrape a little off and put it upon the point of a knife, you find you can burn away the black material, while the grains of sand or clay remain behind. These fragments and layers are evidently only leaves and bits of different plants embedded at the same time as the larger and better preserved fern. Now, how did plants find their way into the heart of a piece of stone?

To understand how this happened we must again go back to what nature is doing at the present time. You remember that when you were watching the runnel coursing down the sloping roadway, you noticed that it sometimes swept along bits of straw, wood, paper, or other loose objects which it managed to reach. Some of these floated away into the nearest drain and were soon lost sight of. But others sank to the bottom of our little pool. Look again at the section we cut open there (Fig. 10), and you will find little chips of wood or straw or leaves and blades of grass among the fine sand and mud left by the rain. These objects lie flat between the thin layers of sediment. And if you think of it, you will understand how that should be the position they would naturally take as they sank to the bottom. Rain therefore can wash away leaves and other pieces of plants, and allow them to drop in a pool, where they become interstratified with the silt, that is, are deposited between its layers and covered over by it.

Again: watch what takes place along the banks or

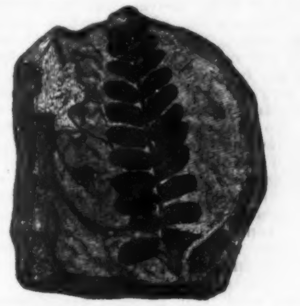


FIG. 12.—Piece of Shale containing portion of a fossil fern.

at the mouth of a river, and you will soon observe that the leaves, branches, and other floating objects carried down by the current in the end sink to the bottom, there to be embedded in and gradually covered up by the growing accumulation of sand and mud. If you dig into any of the deposits along the banks, you meet sometimes with layers of leaves and twigs, grouped in the same stratified way as the sediment above and below them. Such deposits of drifted vegetation often form a conspicuous part of the accumulations of which the delta of a river consists.

But it must happen continually that before the leaves or branches or the trunks of trees have become so saturated or waterlogged as to sink to the bottom, they are borne onward into the sea. In such cases they may float a long way from shore ere they fall to the bottom and become buried in the silt and sand there. Hence, whether in the beds of rivers or at the bottom of lakes or of the sea, the remains of land plants must be constantly dropping among the sedimentary deposits which are gathering there.

You can now see therefore how it is that pieces of ferns or any other kind of land plants should be found in the heart of such a solid stone as our bit of shale. The stone was once merely so much sediment laid down below water, and the fragmentary plants were drifted away from the place where they grew until at last they were buried among that sediment. As the mud hardened into shale, the plant became more and more altered until its substance passed into coal. You will find in a later lesson that coal was formerly vegetation which, buried under great masses of sediment, has been slowly changed into the black glossy substance so familiar to us.

It is not only plants, however, which occur embedded in sedimentary rocks. Here (Fig. 13) is a draw-

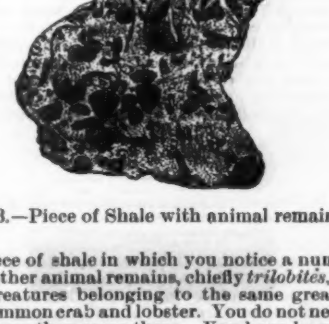


FIG. 13.—Piece of Shale with animal remains.

ing of a piece of shale in which you notice a number of shells and other animal remains, chiefly *trilobites*, that is little sea creatures belonging to the same great tribe with our common crab and lobster. You do not need now to be told how they came there. You have learnt that anything lying at the bottom of the sea or of a lake will be buried in sediment. The remains of shells, corals, fishes, or any other animals which live in the water must gather on the bottom when these animals die, and become embedded, in the silt or other deposit which is there forming. It was clearly in this way that the shells and corals in our piece of shale were preserved.

Did you ever look into the little pools of sea water left upon a rocky beach when the tide has gone back? How full of life they are! Tufts of sea weed sprout up in one place, groups of brightly tinted sea anemones appear in another, periwinkles and limpets cling to the sides, and down at the bottom you may see tiny crabs cautiously creeping out of your sight, with many other kinds of sea creatures moving to and fro of which you do not know the names. If you look a little more narrowly, you can observe that some of the shells at the bottom are empty, the animals which once lived in them having died, and that broken pieces of other dead creatures lie there also.

You are not to suppose of course that the whole of the bottom of the sea is like the bottom of one of these pools on the beach. The plants and animals in the pools are those which live along the shore or shallow parts of the sea, while the deeper parts have other plants and animals peculiar to them. But although these living things differ greatly in different portions of the ocean floor, and though here and there they may be absent from bare patches of gravel, stones or sand, the floor of the great sea resembles the floor of the little pool on the beach in this respect, that it swarms with many kinds of living creatures and with the remains of dead ones. So that the deposits of sand and mud which gather upon the sea bottom must contain abundant relics of these creatures.

If then the remains of plants and of animals are very generally buried in the accumulations of sediment which now increase from day to day at the bottom of lakes or of the sea, we may be sure that the same must have been the case in past times, and that sedimentary rocks, which are only so much hardened sediment of the bottom of old lakes or seas, should also contain remains of plants and animals. And so they do abundantly—you will meet with sandstones, shales, and other sedimentary rocks, as full of such remains as any part of the modern sea bottom is now crowded with life.

Any relic of a plant or animal embedded in rock is called a fossil. The fern in Fig. 12, for example, and the shells and trilobites in Fig. 13 are fossils. Some of the questions which fossils enable us to answer will be pointed out in the next lesson.

V. A Quarry and its Lessons.

In the foregoing lessons you have learned what sediment is, how different kinds of sediment, arranged under water, have become sedimentary rocks, and how they may contain the remains of plants or animals. Let us now try to put some questions to these rocks, and see how they tell their own story.

If you go into the quarries which abound in many parts of this country, you may learn a great deal on this subject. Let us suppose ourselves to be in such a one as that represented in Fig. 14.

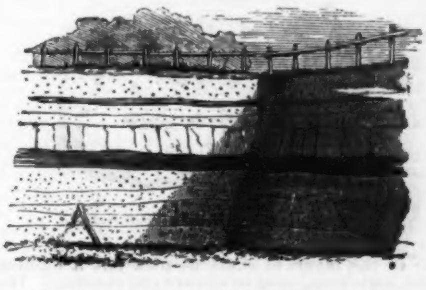


FIG. 14.—Quarry in Sedimentary Rocks.

In the first place, what feature about the quarry strikes you most forcibly when you enter? You answer readily, the stratification of the rocks. They are arranged in layers or beds, one above another, in that stratified arrangement which you have found to be so characteristic of rocks laid down as sediment under water.

In the second place, you observe that they do not all consist of the same materials. Some are of fine conglomerate (marked with little circles and dots in the drawing), others of various kinds of sandstone (marked with finer dots), and some of different sorts of shales or clays (marked with horizontal lines). These beds, or strata, as they are called, alternate irregularly with each other, just as gravel, sand, and mud might be found alternating in the delta of a river or under the sea.

In the third place, let me ask you to point out which are the oldest of the beds. You answer without hesitation that those at the bottom of the quarry must be the oldest, because they certainly were deposited before those lying above them. The lowest bed may be of exactly the same materials and thickness as one or more of the others, and may so precisely resemble them that you might not be able to see any difference between them if you looked at them each by itself. Yet their occurrence one above another would prove them not to be the same bed, but to have been formed at different times one after the other. In all such cases the beds at the bottom are the oldest, and those at the top the newest. This arrangement of one bed or stratum above another is called the order of superposition.

In such a quarry as that drawn in the woodcut, this order is no doubt very simple and self-evident, but you will learn afterward that it is not usually so clear, for in many cases the rocks are concealed from you in part by soil or otherwise, and much care and patience may be needed before their true order of superposition is ascertained. But when, in spite of all difficulties, you succeed in showing which are the bottom rocks and which the uppermost, you at the same time determine which are oldest and which newest.

In the fourth place, let us see if the rocks of this quarry have preserved any evidence as to where they were deposited. We split open some of the lower beds of sandstone and find that their surfaces are often covered with such markings as are shown in the following drawing (Fig. 15). Did you ever see anything resembling these impressions elsewhere? If you have ever walked along a flat, sandy beach, you must have noticed the ripple marks which the shallow rippling water leaves on the soft sand. They are precisely like those on the sandstone. You may see them too along the shelving margin of a lake, indeed wherever water has been thrown by the wind into little wavelets over a sandy bottom. They betoken shallow water. Hence we have learned one important fact from our quarry, as to the origin of these rocks, viz., that they were not deposited in a deep sea, but in shallow water.

We look still further among these strata, and notice at last that some of them are curiously covered with little

round pits, about the size of peas or less. The general appearance of these pitted surfaces is shown in Fig. 16. How did these markings come there? Like the ripple marks they must of course have been impressed upon the sand when it was soft, and before it had been hardened into sandstone. Again, you must seek for an explanation of them by watching what takes place at the present time. You know that when drops of rain fall upon a smooth surface of moist sand, such as that of a beach,

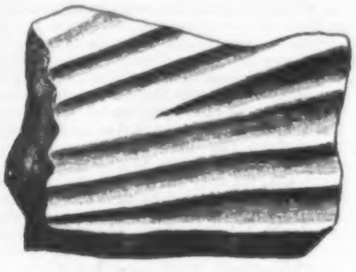


Fig. 15.—Ripple Marks in Sandstone.

they each make a little dent on it. You have learned something about these rain prints, and if you compare the present drawing with the picture of the rain prints in the Physical Geography Primer, Fig. 9, you will see that they are essentially the same, and that they have both been made by the fall of rain drops upon soft, moist sand.

Here then is another fact which throws still more light on the history of these rocks. The ripple marks show that the water must have been shallow; the rain prints prove that it must have risen along a beach liable, now and then, to be laid dry to the air and rain. Now, can we tell whether the water was salt or fresh? in other words, was this beach the shore of a lake or of the sea?

Again we turn to the rocks themselves, and from

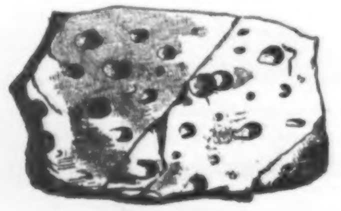


Fig. 16.—Rain Prints on Sandstone.

some of the layers of shale we pick out a number of fossils, which enable us to answer the question. If you were to fish in a lake, would you catch only the same fish which you find in the sea? Certainly not; you would soon learn that not only the fishes, but the other animals and the plants living in fresh water, differ from those living in salt water. Star fishes, limpets, oysters, and flounders, for example, are inhabitants of the sea, while your old friends the perch, the minnow, and the stickleback are natives of rivers and lakes. You can understand, therefore, that the remains of animals and plants preserved in the deposits of the sea bottom must differ from those preserved on the bottoms of lakes.

Some of the fossils which we have picked out are represented in the woodcut (Fig. 17). Of these, *a* is a

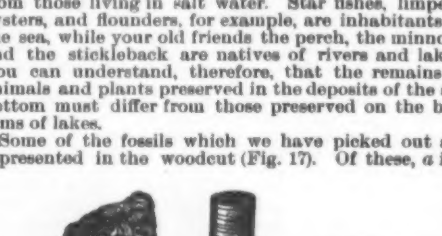


Fig. 17.—Fossils. *a*, coral; *b*, part of encrinite; *c*, *Spirifer*, a marine shell.

coral; *b* is part of the jointed stem of the encrinite or stone lily—an animal related to the common star fish; and *c* is a shell belonging to a family the members of which are all dwellers in the sea. Now these are all unmistakably marine animals, and when we find them associated in this way in a bed of stone, we feel certain that the materials of the stone must have been laid down under the sea; they were possibly cast ashore on the old sea beach, as shells are to this day.

Here, again, is a third fact about the history of our rocks. The ripple marks and rain prints made it certain that they were formed in the shallow water close to shore, and along a beach; and now the fossils prove that those waters were part of the great sea.

In this quarry then you have found clear proofs that land and sea have here changed places. Though the quarry may be in the very heart of the country, far away from the sea, yet you cannot be more sure of anything than that the sea was once upon its site. But if you search among other quarries you will find the same kinds of proofs of the former presence of the sea. In fact, were you to start from the south of England, and go north to the far end of Scotland, by much the largest number of quarries you would meet with would be in rocks which were originally formed under the sea. In such a journey you would learn that almost the whole of our country is made up of such rocks. Down at the bottom of deep mines, and away up at the summits of high mountains, you would come upon them. Nor is Great Britain singular in this respect. Suppose you were to cross Europe and look carefully at all the rocks on your way, you would still find the sea-formed ones to be the great majority. From Europe into Asia, and from Asia through Africa on the one hand, down the whole length of America on the other, you would encounter far more rocks which had been formed under the sea than of any other kind. The very highest mountains in the world consist of sea-made rocks.

Now, is this not a very singular fact? How is it that the solid land has been chiefly made under the sea? The rocks must have been raised up out of the sea by some means, and since the land is so uneven, they would seem to have been raised much more in some places than in others. How this raising of the sea bed has taken place, will be spoken of in a later lesson. But first we must trace the history of certain other rocks, many of which have also been formed under the sea.

ORGANIC ROCKS, OR ROCKS FORMED OF THE REMAINS OF PLANTS AND ANIMALS.

I. Rocks Formed of the Remains of Plants.

Since the leaves, branches, and stems of plants and the shells or other remains of animals are sometimes scattered so abundantly through ordinary sedimentary rocks, it is easy to see that sometimes they may occur in such quantity as to form great deposits of themselves. You could hardly call such deposits sedimentary, in the same sense in which common shale and sandstone are so named. We may term them organic rocks, or, organically derived rocks, because they owe their origin to the accumulation of what are called organic remains or fossils, that is, the remains of plants or animals. A plant or animal lives, moves, and grows by means of what are called organs. For instance, we walk by using our legs, which are our *organs of locomotion;* we speak with our mouth, which contains our *organs of speech;* we see by means of eyes, which are our *organs of sight;* and so on. Every object, therefore, which possesses organs is said to be organized or to be an organism. So that when you see this word organism, you will remember that it means either a plant or an animal, for it is only plants and animals which are really organized.

We begin with those rocks which have been formed out of the remains of plants. As an illustration let me ask you to examine carefully a piece of coal. If you master all that it has to tell you, you will not have much difficulty in tracing out the history of other rocks belonging to this series.

You know well the general appearance of coal. Did you ever notice that, though brought to the fireplace in rough, irregular lumps, it has nevertheless an arrangement in layers like the sedimentary rocks? Try to break a big solid piece of coal, and you find that it usually splits more easily in one direction than in any other. This direction is that of the thin layers of which the coal consists. If you want large pieces of coal to burn up quickly and make a good fire, you will take care so to put them in the grate that those layers shall be more or less upright. In that position the heat splits them up.

Now look at one end of a lump of coal, where the edges of the layers are exposed. You cannot follow them with the same ease as in the case of a piece of shale, for they seem to blend into one another. But you may notice that, among the layers of hard, bright, glossy substance, there occur others of a soft material like charcoal. A mere general look at such a piece of coal would show you that it is stratified.

You know that coal can be burnt away so as to leave only ashes behind, and that in this respect it resembles wood and peat. Chemists have analyzed coal, and found that it consists of the same materials as wood or peat, and that in reality it is only so much vegetation which has been pressed together, and gradually changed into the black substance now used as fuel.

Let us suppose ourselves at a coal mine, with the object of seeing exactly how the coal lies before it is dug out of the earth and broken up into the small pieces which we burn in our grates. (See Fig. 37.) We descend in one of the cages by which the miners are let down into the pit. After our eyes have got a little used to the darkness at the bottom, we set out, lamp in hand, along one of the roadways, and reach at last a part of the pit where the miners are at work removing the coal. Now, first of all, you see that the coal occurs as a bed, having a thickness of a few feet. This bedded character agrees with what you have already noticed as to the internal layers in the stone, and confirms you in believing that coal is a stratified rock. Next observe that the pavement on which the coal rests, and the roof which covers it, are both made of very different materials from the coal itself. Were you to cut a trench or section through pavement, coal, and roof, you would find some such arrangement as in Fig. 18. You would prove beyond any doubt that the bed of coal lies among beds of common sedimentary rock.

But what is this layer marked *b*, forming the floor or pavement on which the coal lies? Examine it with attention, and you recognize it to be a bed of dark clay, with abundance of black streaks and branching strings, like roots, spreading through it. You may trace these

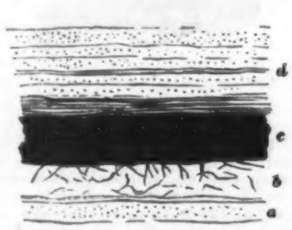


Fig. 18.—Section of a coal seam with its roof and pavement. *a*, sandstones, shale, etc.; *b*, under-clay forming pavement of coal (*c*); *d*, sandstones and shales, forming roof of coal.

root-like strings into the bottom of the very coal itself. If you visited other pits, you would find each coal seam to lie usually on such a bed as this. Now, why should the coal rest rather on a bed of clay or shale than on one of sandstone or any other sort of rock? If you noticed that this peculiar pavement met you in every pit you visited, would you not begin to feel quite sure that the constant association of the coal and its under-clay could not be a mere accident, but must have a meaning?

Now look at the under-clay again. Does it not remind you of a bed of soil with roots branching through it? With this idea suggested to your mind, the more you examine the rock the clearer will this resemblance appear, until you are driven to conclude that in truth the under-clay is an old soil, and the bed of coal represents the vegetation which grew upon it. (See Fig. 38.)

Each coal seam has been in truth at one time a dense mass of vegetation growing on a wide marshy flat, somewhat like the swampy jungles of tropical countries at the present day. These great marshy plains had a bottom of muddy soil on which the rank vegetation grew, and it is this very soil which you still see in the under-clay.

Can we tell anything about the kind of plants which flourished over these plains, and accumulated into the thick mass which formed the coal? Not much can usually be made out from the coal itself, for the vegetation has been so squeezed and altered as to destroy the leaves and branches of the plants; yet in many kinds of coal parts of the old plants have been changed into a sort of charcoal, which soils the finger, and shows traces of the vegetable fiber like any ordinary charcoal. If you cut slices from coal, fix these on glass, rub them down until they are so thin as to be transparent, and place them under a microscope, you may often find that the coal contains millions of little seed vessels, or, as they are called, sporangia. These were shed by plants somewhat like the club mosses of our own moors and hills, but much larger in size, and must have fallen so thickly over the flat grounds as to form a kind of mould or soil upon them.

But though the larger plants have not usually been preserved well in the coal itself, you may sometimes find them in great perfection and beauty in the beds of rock above or below the coal. Some of the common varieties are shown in Fig. 19. Now and then you

Fig. 19.—Plants out of which coal has been formed.

may see these plants lying across each other and all squeezed flat, but still retaining much of their original gracefulness, upon the bottom of the bed of rock which forms the roof of the galleries as you go through the coal mine.

Each coal seam, once a luxuriant surface of vegetation, open to the sunlight, and stretching over many square miles, now lies buried deep within the earth, under huge masses of rock which must be bored through before the coal can be reached. How this burying has taken place we shall find out in a later lesson. In the meantime you should learn a little about another kind of formation, where vegetation comes into play, and which you may examine, not in a deep mine, but in the open day.

You have no doubt read about, you may even have seen, the bogs and peat mosses so abundant in Ireland, Scotland, and some parts of England. If you have not you must imagine a wide, flat space of brown moor and green marsh, in many parts so soft and wet that you would sink deep into the black mire if you tried to walk on its treacherous surface; in other parts having a firmer crust, which shakes under your feet as you jump from one dry standing place to another. Such a flat space is called a bog in Ireland, while in Scotland and England it is known as a moss or peat moss. Of the whole surface of Ireland nearly a seventh part is believed to be occupied with bogs, and in many parts of Scotland too they occur in great numbers.

Visiting one of these places, you notice that round its edges it is usually quite firm. It may even have become so dry over the very center as to be plowed up and to furnish crops of turnips and potatoes. Wherever you can catch a sight of the substance of which the moss consists, you find it to be a black or dark brown sort of mould called peat, formed of the remains of plants firmly matted together. Over the whole of the moss this peat extends as a bed, sometimes thirty or forty feet thick. It is simply a vegetable deposit, and in this and in other respects resembles coal.

Such being its composition, it may of course be readily burnt, so that at the mosses it is dug out in pieces, which are dried and used for fuel. Over great parts of Ireland and wide regions of Scotland the peasantry have no other fuel than this peat, which they cut every summer from the mosses.

In Fig. 20 a representation is given of one of these cuttings for peat. It is in such places that the mode of origin of the deposit can best be studied, and as the tracing out of the formation of a peat moss furnishes a good example of the way in which geologists try to find out the past history of the earth, let me ask you to suppose yourselves looking into the opening which has been made in the peat moss drawn in Fig. 20.

Below the surface of coarse grass and heather lies the peat, a brown fibrous mass in the upper parts, but getting more and more compact toward the bottom, till it passes perhaps into a dark compact substance in which no trace of any fibers may be discernible. Down below the bottom of the peat there sometimes lies a layer of fine clay, containing the remains of shells which are only found living in fresh water. Now and then, too, a rude canoe, hollowed out of the trunk of an oak tree, is dug up from the bottom of a peat moss—a relic of some of our uncivilized ancestors.

Here, then, is a little bit of geological history. Now

put these separate facts together and make out the story of the peat moss.

Beginning at the bottom, the oldest formation you meet with is the layer of clay just referred to. You have already learned that such a layer must have been laid down under water. If it should happen to be thick, it will suggest to you that probably this water was not a mere shallow pool or brook, but had some depth and extent. But the shells indicate further that the water must have been that of a lake, for they are such shells as you might find still living in the lakes of the neighborhood. The first point you settle, there-

FIG. 20.—Section of a peat moss, where the peat is cut and piled into small stacks to dry for fuel.

fore, is that before a peat moss existed here, a lake occupied its site. You may even yet trace what the boundaries of this lake were, for the slopes which rise all round the flat peat moss must in the same way have surrounded the old sheet of water, whereon our rude forefathers floated the canoes which are now and then dug up from the bottom of the mosses.

Above the layer of clay which marks the former lake bottom, comes the bed of peat, made up wholly of vegetable materials. Evidently it has taken the place of the water. The plant remains have filled the shallow lake up, and converted it into a peat moss. In many places you may see this process actually going on still. In such a peat moss, for example, as that shown in Fig. 21, it is evident that the little patch of

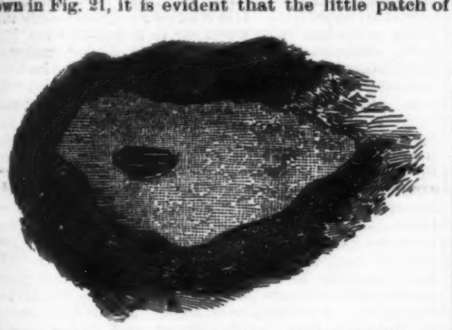


FIG. 21.—Ground plan or map of a peat moss filling up a former lake, and with a portion of the lake still unfilled up.

water in the center is only a remnant of the lake, which once covered the whole hollow. At the edge of that remaining pool you find that the marshy vegetation out of which the peat has been formed is growing into the water on all sides. Put a pole down to the bottom and you will stir up the fine black or brown peat, formed out of decayed roots and fibers. Here there is still some water between the dead peaty matter at the bottom and the growing plants which form a sort of crust over the top. But in the end the plants will fill up the whole of this intermediate space, and then even the center will be converted into a solid bed of peat, as all the outer parts of the moss have already been.

Peat mosses have been formed in marshy grounds or shallow lakes by the growth and decay of plants, and the accumulation of their remains on the place where they lived and died. Like coal seams, they show how, in certain circumstances, the growth and decay of plants may give rise to thick and widespread deposits.

II. Rocks Formed out of the Remains of Animals.

At first when you think of it, there seems not much chance of animal remains accumulating to such a depth as to form any well-marked deposit. Though the air may be filled with insects, though birds in abundance may be seen and heard as the summer slips away, though in our meadows and woodlands rabbits, hares, moles, and many other creatures live in great numbers, yet you nowhere see their remains forming a deposit on the surface. Nay, you comparatively seldom see a dead animal at all. They creep into holes and die there, and their bodies gradually crumble away and disappear. But if you look at the right places, you will discover that the remains of animals as well as of plants, and indeed much more than plants, form great accumulations.

In the bed of clay under a peat moss, the shells which are sometimes to be seen mouldering away belong to certain kinds which live in lakes. In some parts of the country the bottoms of the lakes are covered with similar shells, so much so that if you were to take a boat and begin to dredge up some of the soft mud from the bottom of one of these sheets of water, you would find it to consist of a kind of white chalky substance, or marl, as it is called, made up of shells in all stages of decay. The animals which live in these shells so abound in the water that as they die their shells form a layer over the floor of the lake. Now and then such a lake has been either gradually filled up by being choked with vegetation and silt, or has been drained artificially so as to be converted into dry land. Digging down on the site of that vanished lake, you would come to the fresh water marl, forming a bed or layer several feet, or even yards, in thickness. Perhaps you would meet with the skeleton of some deer, or wild ox, or other animal, which had somehow been drowned in the old lake; or you might disinter the canoe or stone hammer or other relic of the early human races which peopled the country before so many of its lakes and forests had disappeared. In some districts where limestone is scarce, the marl of the old lakes has been dug up in large quantities as a manure for the land. Hence you learn that even the frail shells which are to be seen on the stones and reeds along the margin of a lake may afford an illustration of how rocks are formed out of the remains of animals.

It is on the floor of the great sea, however, that the most wonderful examples occur of the way in which rocks are gradually built up from the remains of animals to a depth of many hundreds or thousands of feet, and over distances of many hundreds of miles. Something has already been said on this subject in the Physical Geography Primer, Arts. 236 and 247; where the use of the dredge for the exploration of the bottom of the ocean was referred to, and allusion was made to the fine mud, formed of minute organic remains, and found over most of the bed of the Atlantic Ocean. Let us now consider this mud a little further.

To the west of Britain the Atlantic soon and suddenly deepens. Its floor then stretches away to Newfoundland as a vast plain, the lowest part of which is about 14,000 feet below the waves. It was over this wide submarine plain that the telegraph cables had to be laid, and hence numerous soundings were made all the way across from Ireland to the American coast. While in the shallower parts of the sea the bottom was found to be covered with sand, gravel, or mud, from the deeper parts there came up with the sounding lead a peculiar gray sticky substance known as ooze, which must stretch over that wide deep sea basin for many thousands of square miles. This ooze, when dried, looks like a dirty kind of chalk. You may purchase a minute quantity of it prepared on a glass slide for the microscope. Looking at such a slide with only your naked eyes, you might suppose that the little specks you see are merely so many grains of dust upon the glass. But place them under a strong magnifying glass or microscope, and you discover that they consist of minute shells called foraminifera, some of them quite entire, others broken, and all most delicately sculptured and punctured (Fig. 22). As you look at these graceful

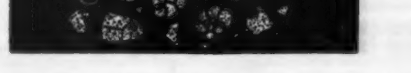


FIG. 22.—Some of the ooze from the Atlantic bed, magnified 25 times.

forms, reflect that they are crowded together, millions upon millions, over the floor of the Atlantic, that as they die their shells gather there into a widespread deposit, and that as fresh generations spring up one after another this deposit is continually getting deeper. After the lapse of centuries, if the deposit were to remain undisturbed, and if we could set a watch to measure its growth, we should find it to have risen upward and to have inclosed the remains of any star fishes or other sea creatures which chanced to die and leave their remains upon the bottom. Hundreds of feet of such slow-formed deposit have no doubt already been laid down over the bottom of the ocean between Ireland and Newfoundland. Here then is a second and notable example of how a deep and far-spread mass of rock may be formed out of the remains of animals.

Now return once more to our piece of chalk and compare it with the ooze of the Atlantic. At the first glance in many a piece of chalk you can see shells, corals, sea urchins, and other marine remains, either entire or in fragments (Fig. 23). These are enough to

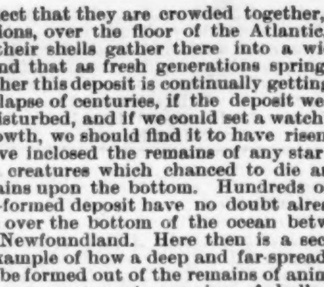


FIG. 23.—A piece of chalk with shell in it.

convince you that chalk must have been formed under the sea. But a little further examination will show that the chalk not merely contains animal remains, but is altogether made up of them. If you were fortunate in the piece of chalk, which you treated as recommended in a former lesson, you found numerous little cases or shells (Fig. 3), quite like those in the Atlantic ooze (Fig. 22), along with fragments of larger broken shells and other remains. The whole of the chalk is evidently made of animal remains, some quite perfect, others so broken and crumbled that you cannot be sure to what kind of sea creatures they belonged. You must not be disappointed if for a time none of the chalk which you brush off shows you any distinct organism, but only shapeless white grains. All these grains are only the mouldered fragments of organisms, and you must search among them until you find some still perfectly preserved and entire specimens. When successful you will meet with some such assemblage of minute organic remains as shown in Fig. 3, which represents some of the chalk of Gravesend.

But chalk is only one of many rocks composed altogether of the remains of animals. Most of the limestones have been formed out of these materials. Here, for instance, is a piece of limestone (Fig. 24) which has been lying exposed to the air for many years, and you see how its surface is crowded with bits of "stone lilies," corals, shells, and other remains. The sight of such a piece of stone as this at once sets you thinking about some old sea floor. You can picture to yourselves how all these delicately sculptured little fragments once formed parts of living creatures which moved or grew beneath the clear waters of the sea. The bit of limestone becomes to you a kind of model of what a sea floor must be, and reminds you of what you may even have seen with your own eyes at the bottoms of some of the rocky pools upon the beach.

FIG. 24.—Piece of limestone, showing how the stone is made up of animal remains.

If a little fragment of limestone might suggest these thoughts to you, what would you think if you were taken to places where all the hills are made up of such limestone—vast piles of rock two or three thousand feet thick, and stretching over the land for hundreds of square miles? And yet you may meet with such wonderful masses of limestone, crowded with the remains of old sea creatures, in almost every country of the world. In Britain, for example, the hills and dales of a great part of Derbyshire and Yorkshire are built up of limestone. Looking up one of these wonderful valleys, you see the beds of limestone winding along either side and rising in broad terraces, one above the other as far as the eye can reach. In walking along the surface of one of these high hill terraces, you are really walking on the bottom of an old sea, and if you stop anywhere to look at the rock under your feet, you will see that it is only a mass of the crowded remains of the little animals which peopled the waters of that sea. Somehow the sea bed has become dry land, and the thick animal deposits of its bottom have hardened into limestone, out of which high hills and wide valleys have been formed.

Still thicker masses of similar limestone occur in Ireland. Some of the giant mountain chains of the world consist in great measure of limestone. Among the lofty crests of the Alps, for example, and in the chain of the Himalaya, limestone made up of the remains of marine animals is found to constitute great ranges of the high ground on which the eternal snows rest and from which the glaciers descend into the valleys.

Summary.—Before advancing further you may now look back upon what you have learned, and see exactly the point to which you have come. If I were to ask you to make a short abstract of the foregoing lessons, you would probably jot down such a summary as the following:

(1.) The surface of the land is worn away by rain and by streams, and a vast deal of mud, sand, and gravel is consequently formed.

(2.) This material worn from the land accumulates at the mouths of rivers, in lakes, and over the floor of the sea, so as to form great deposits, which will in the end harden into sedimentary rocks.

(3.) Leaves, twigs, trunks, and other parts of plants, together with the remains of animals, become embedded and preserved as fossils in these sedimentary accumulations.

(4.) Plants and animals of themselves sometimes form thick and extensive deposits upon the surface of the earth.

(5.) The rocks of which the dry land is made have been formed, for the most part, under the sea.

(6.) Old land surfaces which, like the coal seams, once spread out into luxuriant forests, are now buried deep beneath the present surface under masses of solid rock.

You have advanced step by step to these conclusions, and are quite sure of them, for you have tested everything on the way. Again and again you have met face to face with proofs that in some way or other land and sea have often changed places. You have found old sea bottoms even up among the crests of the mountains. You have found old forests buried in the form of coal seams deep in the bowels of the earth. How can these wonderful changes have taken place? To be able to answer this question you must find out something about the history of the third of the three great groups into which we divided the stones of the earth—the igneous rocks.

(*To be continued.*)

DARKENING A LECTURE ROOM.—The lecture room in the physical laboratory at Cornell University is provided with a novel means of darkening it, for the purpose of projecting views on a screen, or for any experiment requiring a dark room. The shutters to the windows are suspended on cords which pass over pulleys, and then joined to a single weight sufficient to balance all the shutters, and situated in the basement. A long cylinder situated under this weight is connected with the water supply, and the piston rod raises this weight whenever the water is admitted into the cylinder, and whenever the water is released from the cylinder, the falling of the weight closes the window shutters. This apparatus is managed by a small lever at the reading stand at the desk on the platform, so that the lecturer can, without any unusual effort, either lighten or darken the room according to the immediate needs of his lecture.

[NATURE.]

THE OPENING OF THE MARINE BIOLOGICAL LABORATORY AT PLYMOUTH.

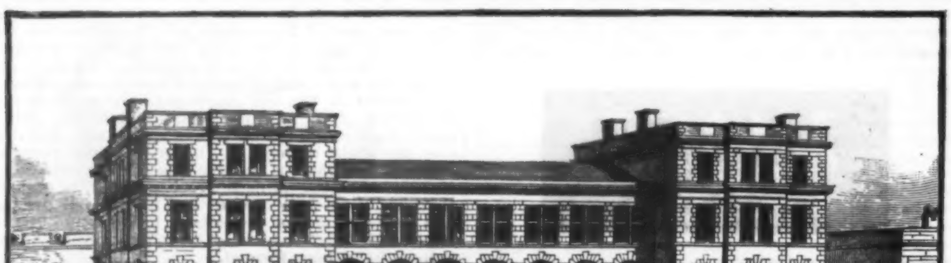
THE laboratory at Plymouth, which is now ready for work, is remarkable as being the first institution in this country designed purely for scientific research which has been originated and firmly established by the efforts of scientific men appealing to the generosity and confidence of wealthy individuals and corporations who desire the progress of knowledge for practical ends and the general good of the community.

It may be said that the Marine Biological Association began its active career on June 30.

On that day Prof. Flower, on behalf of the Association, declared the laboratory at Plymouth, which is now complete, open for the purposes of biological research. The opening of the laboratory may be said to mark an epoch in English zoological science, just as the opening of the Stazione Zoologica at Naples, which is essentially a German undertaking, marked an epoch in German science. It is true that small seaside laboratories have already been established in the United Kingdom—at Granton, St. Andrews, and Liverpool Bay; but none of them can compare with the present undertaking in size and importance, and none can offer such advantages to the investigator.

The present institution, it may be remembered, is historically the outcome of the International Fisheries Exhibition held in London in 1883. That exhibition served partly as an amusement to Londoners, but it also performed a far more important service—it directed people's minds toward the importance of our fisheries, and made them in some slight degree acquainted with the conditions under which those fisheries are worked. At the close of the exhibition a large balance was left in the hands of its promoters, and it was hoped by many leading men of science that the money thus obtained would be utilized, in part at least, for the purpose of encouraging investigations upon the habits and economy of food fishes. But the money was appropriated to other purposes, excellent in themselves, though useless as a means of promoting the welfare of the fishing industry.

Prof. Lankester, however, nothing daunted by this want of success in obtaining funds from the surplus of the Fisheries Exhibition, and feeling that it was time to strike while people's minds were awakened to the importance of our fisheries and to the lack of scientific knowledge concerning them, determined to found an association for the purpose of encouraging the study of the marine fauna of the British coasts, and with the consent and co-operation of the officers of the Royal Society called a meeting for this purpose, in the rooms of the society, on March 31, 1884. The meeting was eminently successful. The Duke of Argyll proposed a resolution to found the Marine Biological Association of the United Kingdom, and was supported by the most eminent biologists in the country. An appeal was made for subscriptions in aid of the association's projects, and was soon liberally responded to. His Royal Highness the Prince of Wales graciously consented to be patron of the association, and gave liberally to its funds; the scientific societies, the City companies, the universities, and finally her Majesty's government, joined the list of subscribers; and in a short time the association was in a position to undertake the building of a laboratory. After some debate as to the most suitable locality for a laboratory, Plymouth was selected, partly because it is a large and important fishing port, partly because the richness of the marine fauna of the Sound and neighboring shores was extolled by such eminent authorities as the late Dr. Gwyn Jeffreys, Mr. C. Spence Bate, and Prof. Charles Stewart. The association was fortunate in securing a magnificent site for the laboratory from the War Office. For this site, than which a better could not be found, the association is greatly indebted to the Earl of Morley, then Under-Secretary of State for War, and to Sir Andrew Clarke, Inspector-General of Fortifications. The site granted is that part of the fosse of the citadel lying to the south of the portion of the citadel known as King Charles' Curtain; it has a frontage toward the sea of 265 ft., and extends some 240 ft. southward of the citadel.



SOUTH FRONT OF THE LABORATORY OF THE MARINE BIOLOGICAL ASSOCIATION, ON THE CITADEL HILL, PLYMOUTH.

The laboratory, which has been erected upon this site, is admirably adapted to the purpose of the association. It is, indeed, more than a laboratory, it is also an aquarium, whose tanks are extensive and fitted with every improvement that modern science can suggest. The total cost of building, machinery, and fittings, including all fees, has been about £12,500. The structure comprises a central portion, with a wing at either end. The east wing is almost wholly taken up by the residence of the director, and needs no further comment. The west wing has on the ground floor the caretaker's rooms, and a receiving room, into which the results of the day's fishing will be brought for examination. On the first floor are chemical and physiological laboratories and on the second floor a library, a work room, and lavatory. The main part of the building contains on the ground floor the aquarium or tank room, and on the first floor the large laboratory. The tank room is fitted with slate and glass tanks, of which one on the northern side is a noble window tank, 30 ft. in length, 9 ft. in breadth, and 5 ft. deep. There are three large window tanks on the north side, nine smaller window tanks on the south side, and a series of five table tanks in the middle of the room. The tanks are supplied with salt water from two reservoirs, capable of holding 50,000 gallons each.

From these the salt water is led by means of pumps through vulcanite pipes into the tanks; the openings of the pipes are placed rather more than a foot above the level of the water in the tanks, and are provided with nozzles through which the water is forced at high pressure, so as to form jets descending deep into the tank and carrying with them a quantity of atmospheric air. Circulation has been established in the tanks for the last fortnight, and there is every reason to be satisfied with the arrangements for aerating the water. The jets, carrying down the air deep into the water of the tank, cause it to be filled with minute bubbles, so as to resemble champagne, and all the animals that have hitherto been placed in the tanks are thriving in a remarkable manner, which is the more surprising as new tanks are generally supposed to be highly injurious to organisms introduced into them at an early date. It would be too much to expect that tanks which have been so lately put up should be fully stocked within a fortnight, nevertheless they will present to the visitors a sufficiently interesting collection of local marine forms. For the rest, the tank room is a plain room, without any attempt at ornamentation. It is felt that the scientific nature of the institution must be kept in the foreground, and therefore nothing has been done to make the aquarium a place of popular amusement.

The main laboratory is at present fitted with seven compartments, each to contain a single naturalist, along its north side. When the necessity arises, similar compartments will be placed along the south side. In the center of the room is a series of slate and glass tanks supplied with salt water from the circulating pumps. Beneath these a convenient shelf has been arranged, so that naturalists will be able to arrange for themselves any temporary apparatus that they may devise on as small a scale as is desired. All the arrangements for laboratory work are completed, and the only thing now required is a company of ardent naturalists ready to undertake the work that lies to hand.

The material for work and for stocking the tanks is obtained from the Sound and the sea outside the breakwater by means of the trawl, dredge, and tow net. In general a small shrimp trawl is used in preference to a dredge, as it is much wider and equally effective in collecting the animals that live at the bottom. Hitherto the association has been content to hire fishing boats for dredging and trawling. Most of the work has been done in a small hook and line boat, the Quickstep, of about 6 tons burden, and on special occasions the trawler Lola, of 50 tons burden, has been hired. But this method of hiring is too expensive to be continued; the association will soon have to purchase boats, and probably will find it necessary to acquire a steamboat. Without a steamboat the station is at the mercy of the weather. If it is a dead calm—and calms are frequent in summer along the south coast—no dredging or surface netting can be done—a cruel fate when one knows that the pelagic surface fauna swarms thickest on bright, calm days. Or if it is wished to explore a certain region on a certain day, if the winds prove contrary, more than half the day is lost in beating up to the station; in any case, one may generally expect to have a contrary wind on either the outward or the homeward journey. Such losses of time and material are most prejudicial to an institution like the Marine Biological Association. A steam launch has been found necessary at all other marine stations. Dr. Dohrn has two, the Johannes Muller and the Francis Balfour, at Naples; and the Granton station is well provided for by the steam yacht Medusa. But the funds of the association have been well nigh exhausted in the building of the laboratory. If a steam launch is found requisite, it will be necessary to make another appeal to its friends, which, let it be hoped, will be as heartily responded to as the first appeal for funds for building the laboratory.

It was stated in the early part of this article that the association began its active existence on June 30. It would have been more proper to say its active public existence, for its staff has been active for some time past. Under the guidance of Mr. W. Heape, the late superintendent, a careful though necessarily incomplete exploration of the Sound has been made, and numbers of animals have been identified, preserved, and put aside for future reference. Mr. Heape has also drawn up a complete list of the fauna and flora of the Sound, as recorded up to the present date, and a very formidable list it is.* Botanists will note that there are more than 250 species of marine Algæ recorded from the neighborhood, and some of them are extremely rare. Zoologists will see that there is an unlimited field in certain groups, particularly in the Crustacea and the Mollusca, but that some of the most interesting forms, the "pets of the laboratory," such as Amphioxus and Balanoglossus, are absent. But to say that they are absent means only that other less familiar forms are present, and that these old favorites have not been recorded. A good authority states that Amphioxus can be found in the immediate neighborhood, while it is confidently expected that both Balanoglossus and Amphioxus can be introduced from the Channel Isles, and kept alive in the tanks. The zoologist need not fear that he will be hindered by the poverty of the fauna; there is material enough and to spare. The remarkable Hydroid, *Myriothela*, occurs at low tide, marked in considerable quantities. The interesting Actiniæ, *Edwardsia* and *Peachia*, are to be found. Appendiculariæ and Sagittæ are taken in hundreds in the tow net. *Antedon rosaceus* is abundant a quarter of a mile from the laboratory, and magnificent specimens of Pinna will attract the interest of the malacologist.

Such an institution as that of Plymouth challenges comparison with Dr. Dohrn's famous zoological station at Naples. But there is this remarkable difference between them. The Naples station was founded for purely scientific objects; it does not profess to undertake investigations for the benefit of economic interests. The Marine Biological Association receives an annual grant from the treasury, on the express understanding that it shall conduct researches upon questions relating to the life history and habits of food fishes. It must not be supposed that this work is not scientific because it has a practical object in view. Science is not only the art of thinking correctly, but of observing and recording correctly, and correct observations and records of the life history of our food fishes are just what are wanted at the present time. The work of Mr. J. T. Cunningham, naturalist of the association, is an admirable example of scientific method as applied to a practical investigation. Mr. Cunningham has been working for several months at the development of fishes, with the view of obtaining and artificially fertilizing their ova and rearing their young in captivity. His results are necessarily incomplete, as he has been working in a half-finished laboratory, without gas or water, and under unfavorable conditions as regards boats and men. But he has succeeded in tracing out the life history of the "merry sole" (*Pleuronectes microcephalus*), and has acquainted himself with such important facts concerning the development of the common sole that he confidently expects to be able to hatch out the young next season, his experiments this year having failed only for want of the proper apparatus. He has also recorded the interesting fact that the herring spawns continuously from January to June in the Channel, and appears to have no definite breeding season, as it has in northern waters; and has discovered important facts relative to the breeding of the mackerel, conger, and pilchard, which will be made public as soon as his researches are complete. He has now stocked one of the large tanks in the aquarium with conger, and hopes in a short time to give a final opinion on the obscure question of the breeding of this fish. Not less interesting than Mr. Cunningham's researches are those of Mr. Weldon on the breeding of the common lobster and the rock lobster or craw-fish (*Palinurus*). Another of the tanks in the aquarium is occupied by the "berried" females of these forms, whose bright colors and active movements are as attractive to the casual spectator as their study is interesting to the zoologist and fisherman. So much has been done already by Messrs. Cunningham and Weldon under the most unfavorable conditions that it cannot but be anticipated that when a number of investigators are working under favorable conditions on different groups, but with a common object in view, results of the greatest scientific and practical importance will acrue.

The ceremony on June 30 was interesting and important. Many of the leading biologists in England were present, but unfortunately the eminent president of the Association, Prof. Huxley, was absent on account of ill-health, and so, unfortunately, was Prof. Moseley, one of its most ardent and generous supporters. The Fishmongers' Company added to their munificent patronage of the institution by undertaking the entertainment of the numerous guests who had been invited to the ceremony; and the Association was launched on its career of usefulness in a manner worthy of its aspirations, and satisfactory in the highest degee to its energetic promoters. G. C. B.

PERSONAL IDENTIFICATION AND DESCRIPTION.†

PERHAPS the most beautiful and characteristic of all superficial marks are the small furrows with the intervening ridges and their pores that are disposed in a singularly complex yet even order on the under surfaces of the hands and the feet. I do not now speak of the large wrinkles in which chiromantists delight, and which may be compared to the creases in an old coat or to the deep folds in the hide of a rhinoceros, but of the fine lines of which the buttered fingers of children are apt to stamp impressions on the margins of the books they handle, that leave little to be desired on the score of distinctness. These lines are found to take their origin from various centers, one of which lies in the under surface of each finger tip. They proceed from their several centers in spirals and whorls, and distribute themselves in beautiful patterns over the whole palmar surface. A corresponding system covers the soles of the feet. The same lines appear with little modification in the

* Mr. Heape's list will be published in the forthcoming number (No. II.) of the Journal of the Marine Biological Association.

† Abstract from a lecture given by Francis Galton, F.R.S., at the Royal Institution, on Friday evening, May 25, 1888.

hands and feet of monkeys. They appear to have been carefully studied for the first time by Purkinje in 1822; since then they have attracted the notice of many writers and physiologists, the fullest and latest of whom is Kollman, who has published a pamphlet upon them, "Tastapparat der Hand" (Leipzig, 1883), in which their physiological significance is fully discussed. Into that part of the subject I am not going to enter here. It has occurred independently to many persons to propose finger marks as a means of identification. In the last century, Bewick, in one of the vignettes in the "History of Birds," gave a wood cut of his own thumb mark, which is the first clear impression that I know of. Some of the latest specimens that I have seen are by Mr. Gilbert Thomson, an officer of the American

FIG. 1.—ENLARGED IMPRESSIONS OF THE FORE AND MIDDLE FINGER TIPS OF THE RIGHT HAND OF SIR WILLIAM HERSCHEL, MADE IN THE YEAR 1860.

Geological Survey, who, being in Arizona, and having to make his orders for payment on a camp sutler, hit upon the expedient of using his own thumb mark to serve the same purpose as the elaborate scroll engraved on blank checks—namely, to make the alteration of figures written on it, impossible without detection. I possess copies of two of his checks. A San Francisco photographer, Mr. Tabor, made enlarged photographs of the finger marks of Chinese, and his proposal seems to have been seriously considered as a means of identifying Chinese immigrants. I may say that I can obtain no verification of a common statement that the method is in actual use in the prisons of China. The thumb mark has been used there as elsewhere in attestation of deeds, much as a man might make an impression with a common seal, not his own, and say,

FIG. 2.—POSITIONS OF FURROW HEADS AND BIFURCATIONS OF FURROWS, IN FIG 1.

"This is my act and deed;" but I cannot hear of any elaborate system of finger marks having ever been employed in China for the identification of prisoners. It was, however, largely used in India, by Sir William Herschel, twenty-eight years ago, when he was an officer of the Bengal Civil Service. He found it to be most successful in preventing personation, and in putting an end to disputes about the authenticity of deeds. He described his method fully in *Nature* in 1880 (vol. xxiii., p. 76), which should be referred to by the reader; also a paper by Mr. Faulds in the next volume. I may also refer to articles in the American journal *Science*, 1886 (vol. viii., pp. 166 and 212).

The question arises whether these finger marks remain unaltered throughout the life of the same person. In reply to this, I am enabled to submit a most interesting

FIG. 3.—ENLARGED IMPRESSIONS OF THE FORE AND MIDDLE FINGER TIPS OF THE RIGHT HAND OF SIR WILLIAM HERSCHEL, MADE IN THE YEAR 1888.

piece of evidence, which thus far is unique, through the kindness of Sir William Herschel. It consists of the imprints of the first two fingers of his own hand, made in 1860 and in 1888 respectively; that is, at periods separated by an interval of twenty-eight years. I have also two intermediate imprints, made by him in 1874 and in 1883 respectively. The imprints of 1860 and 1888 have now been photographed on an enlarged scale, direct upon the engraver's block, whence Figs. 1 and 3 are cut; these woodcuts may therefore be relied on as very correct representations. Fig. 2 contains the portion of Fig. 1 to which I am about to draw attention. On first examining these and other finger marks, the eye wanders and becomes confused, not knowing where to fix itself; the points shown in Fig. 2 are those it should select. They are those at which each new furrow makes its first appearance. The furrows may originate in two principal ways, which are not always clearly distinguishable: (1) the new furrow may arise in the middle of a ridge; (2) a single furrow may bifurcate and form a letter Y. The distinction between (1) and (2) is not greatly to be trusted, because one of the sides of the ridge in case (1) may become worn, or be narrow and low, and not always leave an imprint, thus converting it into case (2); conversely, case (2) may be changed into (1). The position of the origin of the new furrow is, however, none the less defined. I have noted the furrow heads and bifurcations of furrows in Fig. 1, and shown them separately in Fig. 2. The reader will be able to identify these positions with the aid of a pair of compasses, and he will find that they persist unchanged in Fig. 3, though there is occasional uncertainty between cases (1) and (2). Also there is a little confusion in the middle of the small triangular space that separates two distinct systems of furrows, much as eddies separate the stream lines of adjacent currents converging from opposite directions. A careful comparison of Figs. 1 and 3 is a most instructive study of the effects of age. There is an obvious amount of wearing and of coarseness in the latter, but the main features in both are the same. I happen to possess a very convenient little apparatus for recording the positions of furrow heads. It is a slight and small but well-made wooden pentagraph, multiplying fivefold, in which a very low power microscope, *with coarse cross wires*, forms the axis of the short limb, and a pencil holder forms the axis of the long limb. I contrived it for quite another use—namely, the measurement of the length of wings of moths in some rather extensive experiments that are now being made for me in pedigree moth breeding. It has proved very serviceable in this inquiry also, and was much used in measuring the profiles spoken of in the last article. Without some moderate magnifying power, the finger marks cannot be properly studied. It is a convenient plan, in default of better methods, to prick holes with a needle through the furrow heads into a separate piece of paper, where they can be studied without risk of confusing the eye. There are peculiarities often found in furrows that do not appear in these particular specimens, to which I will not further refer. In Fig. 2 the form of the origin of the spirals is just indicated. These forms are various; they may be in single or in multiple lines, and the earlier turns may form long loops or be nearly circular. My own ten fingers show at least four distinct varieties.

Notwithstanding the experience of others to the contrary, I find it not easy to make clear and perfect impressions of the fingers. The proper plan seems to be to cover a flat surface, like that of a piece of glass or zinc, with a thin and even coat of paint, whether it be printers' ink or Indian ink rubbed into a thick paste, and to press the finger lightly upon it so that the ridges only shall become inked, then the inked fingers are pressed on smooth and slightly damped paper. If a plate of glass be smoked over a paraffin lamp, a beautiful negative impression may be made on it by the finger, which will show well as a lantern transparency. The blackened finger may afterward be made to leave a positive impression on a piece of paper, that requires to be varnished if it is to be rendered permanent. All this is rather dirty work, but people do not seem to object to it; rivalry and the hope of making continually better impressions carries them on. It is troublesome to make plaster casts; modeling clay has been proposed; hard wax, such as dentists use, acts fairly well; sealing wax is excellent if the heat can be tolerated; I have some good impressions in it. For the mere study of the marks, no plan is better than that of rubbing a little thick paste of chalk ("prepared chalk") and water or sized water upon the finger. The chalk lies in the furrows and defines them. They could then be excellently photographed on an enlarged scale. My own photographic apparatus is not at hand, or I should have experimented in this. When notes of the furrow heads and of the initial shape of the spiral have been made, the measurements would admit of comparison with those in catalogued sets, by means of a numerical arrangement, or even by the mechanical selector described in the last article. If a cleanly and simple way could be discovered of taking durable impressions of the finger tips, there would be little doubt of its being serviceable in more than one way.

In concluding my remarks, I should say that one of the inducements to making these inquiries into personal identification has been to discover independent features suitable for hereditary investigation. It has long been my hope, though utterly without direct experimental corroboration thus far, that if a considerable number of variable and independent features could be catalogued, it might be possible to trace kinship with considerable certainty. It does not at all follow because a man inherits his main features from some one ancestor, that he may not also inherit a large number of minor and commonly overlooked features from many ancestors. Therefore it is not improbable, and worth taking pains to inquire whether each person may not carry visibly about his body undeniable evidence of his parentage and near kinships.

PERSONAL IDENTIFICATION.

IT is generally held that men have attained their natural stature about the age of twenty-four. It may, in addition, be desirable to ascertain to what appreciable extent difference of facial dimensions ensues between the ages of say fourteen and twenty-four. In the celebrated Tichborne case, the differences to be determined lay between portraits taken at the age of twenty-five and those taken at the age of forty and onward. During subsequent life—excepting from the loss of teeth, which would deduct proportionately from the depth of the chin—no appreciable change in the osseous fabric can be theoretically assumed.

Externally, appearances may differ much; but in that case the issues raised are mostly those of beard or no beard, fat cheeks or lean cheeks, blotches, wrinkles, and crows' feet; or no blotches, wrinkles, and crows' feet. Now, without doubt, fatness in lieu of leanness produces a very perceptible difference to the eye, and with superficial observers might invalidate the admeasurement. But such must be reminded that superior plumpness constitutes simply a straight out projection, that adds not a fraction to the flat surface of the picture. Within the boundaries of the area measured, the same identical proportions and distances subsist between the eyes, the lips, and the chin. In a photograph—whether the object be as rotund as a globe or as flat as a dinner plate—no possible difference can ensue if the diameters are in agreement.

Here, perhaps, I may suitably pause, leaving to a future opportunity some of the additional and more vital of the issues involved. The portrait here ap-

pended will answer fairly well the purpose of illustrating the principles of the admeasurement.

It will be seen that through the exact center of the pupils a line is drawn, from side to side (marked 0 in the portrait); and thus is secured the first necessity, a valid horizontal, and a basis for all further operations. Bringing the distance between the centers of the pupils to our aid, we next strike intersecting arcs above and below the horizontal; upon these arcs being connected by a line passing through the points of their intersection, we arrive at the indispensable requisite, the true perpendicular and natural poise of the head, as it variously exists in each portrait.

That feature of the operation having been carefully effected, we proceed with equal care to mark off the lines representing the diameter of the iris, upward and downward—starting always from the center of the pupils.—*W. Mathews, The Photographic News.*

THE SPANISH SAFFRON TRADE.

IN the last issue of the *Handels Museum*, Mr. Theodor Mertens, of Valencia, gives some particulars about the Spanish saffron trade. The average yield of the crop in that country amounts to between 180,000 and 225,000, a quantity four-fifths of which is quite sufficient to cover the entire consumption of Spanish saffron, so that in seasons of abundant crop, when, perhaps, 290,000 to 310,000 lb. are harvested, a heavy stock accumulates, and three successive abundant crops generally cause the farmers to reduce their plantations. The lowest price at which saffron growing can be made to pay closely approaches the equivalent of 28s. 6d. per lb.

At Pithiviers, in the Gatinais (France), a maximum crop of from 27,000 to 34,000 lb. was harvested in former years, but since the severe frost, which occurred in that district in 1879 the largest crop has not exceeded 11,000 lb. (in 1887 it was only about 7,800 lb.), and at present Spanish saffron unquestionably rules the market. The average Italian crop may be placed at 11,000 to 13,500 lb. per annum, and in Austria saffron growing only pays if the price is at least 53s. per lb.

This Austrian is the best of all, and next to it ranks the Gatinais, the only drawback of which is that it very quickly loses its vivid color. In Spain saffron is divided into five grades, each cultivated in a different district. The center of the export trade is Valencia, where the saffron is stored by the merchants, who generally advance money on it to the cultivators. These merchants sell it to the local agents of foreign houses, who export the drug in strong wooden cases, with an outer covering of matting, about 160 lb. weight, and in which the saffron is packed in white paper. For export to distant countries, however, the saffron is generally packed in tins, which are placed in a wooden case.

The principal buyers of Spanish saffron are a few firms in southern Germany—Mannheim, Frankfort-a-M., Hanau, and Wurzburg—who pick and grade it, remove the yellow threads, leaving only the purely red filaments, or grind it, and redistribute it subsequently to all parts of the world. Pithiviers and Marseilles used to buy large quantities in Spain, but do not now take quantities of any importance. Other countries purchasing direct from Spain are England, North America (California), South America, especially Buenos

Ayres, Montevideo, and certain portions on the west coast, British India and Japan. Adulteration is, of course, practiced to a very large extent; at Noveida, in the province of Alicante, for instance, all the saffron brought to market is systematically adulterated.

GUARANA AND ITS HOME.*

By Dr. H. H. RUSBY.

THE home of the guarana is a very different region from that of the coca, although it forms part of the same great region. The great forest plains of Brazil, if they were grass-covered, would present an appearance very similar to that of the Northern prairies, except that over the greater portion the surface of the country is so level that there is little to separate the rivers. During part of the year very little traveling occurs in this country. The rivers, which unite to form the Madeira, in this section at certain seasons of the year all unite to form one vast lake, and a greater part of the country is under water. It is no uncommon occurrence to see the water flowing up streams as the level of a stream is raised higher than that of the other which ordinarily flows into it, by means of additions higher up. The smaller streams have an almost imperceptible current. They are extremely deep and narrow. I have parted the brush from the mouth of a stream which was narrow, but which had a depth of fifteen or twenty feet. The banks of this stream would be so covered with vines that you could hardly land. You could hardly penetrate for a single foot. Progress is prevented by the rushes, the driftwood and the brush. After this region is passed, there is a belt of peculiar trees called "ambaibas," about the size of our ordinary forests of maple, poplar and small oaks, yet it is noticeable only as a fringe to the neighboring frowning forest which towers up behind it. Vines fall down over the trees of smaller growth, covering them like a mantle, and in many places falling into the water. Back of that occurs the canebrake of various species of bamboo, three miles in width, and then you reach the forest proper.

Here there are no such obstacles as you find in the mountains. The travel is not so difficult. There will be long stretches where we can thread our way with success, then we come again to the jungle where the tangle commences. Once there we have to force our way; cutting our way is not practicable, for every time you cut something else falls in your way. There is nothing to do but to place your shoulders against the mass and simply push your way through. Among this canebrake run several species of deer and a great number of tapirs, and it is the home of the prowling jaguar, which lies in wait for other animals, as does the alligator. Here, too, we are liable to encounter enormous anacondas.

Once you get to an installment of the forest proper, instead of having bright butterflies and singing birds, you reach a region which is more like a region of death. The surface of the earth is covered, it is true, with vegetable growth, but it is at the summit of the trees one hundred and fifty feet above us. If you could look on the surface of this forest it would be a mass of green, but you are below, and it is like a subterranean region with only a dark twilight, and it is all silent like the grave. There is a damp earthy smell to the air, which is never penetrated with the rays of the sun. The trees are often as thick as in our own forests. We can only imagine what scientific treasures we could secure were this upper region accessible to us. After all, the region is richer in vegetable growth than the mountain region, but it is so far above us we cannot see it.

Such is the home of the guarana. This is one of the smallest vines which border the watercourses above described. Unlike coca, its origin is easily apprehended. The Sapindaceæ family is largely represented in Brazil, especially by three genera of climbing vines. This one is found wild in many parts of this region. The stem appears like three cylindrical pieces amalgamated into a triangular stem. Its branches are long and slender, climbing by their tendrils.

With the wild plant we have nothing to do. The collection of the drug from the wild plant in this region presents insuperable difficulty. The plant has long been cultivated in the region of the lower Madeira. Here it presents a very different aspect from what it does in the wild state. It is planted out just as a vineyard is planted, except that it is planted wider apart and trained to poles the same as hops. The plant is kept within bounds by pruning. The ripening of the seeds is shown by the opening of the pods. Immediately upon this the fruit is gathered, to prevent the inevitable loss which would occur from its falling. This fruit resembles the hickory nut. It is contained in a husk, which husk consists of three instead of four parts. From these the seeds are shelled out by hand as hickory nuts are. First they are washed free from a phlegmy substance and then subjected to a roasting process of six hours' duration, which loosens from them a papery shell, which is removed by placing them in sacks, and beating them with clubs.

The best varieties of guarana are those in which the seeds have not been very finely broken. A small amount of water is then added, just sufficient to form a mass. It is kneaded by hand into a mass of the consistency of dough. I have been informed that the common belief in this country is that other materials are added to this mass by which it is adulterated. The fact is that other things are not generally so added. A large building is then utilized for the drying purpose. Upon the upper floors of this building this material is spread out and subjected to a slow fire of fuel selected with a view of making no smoke, the object being to keep the temperature equable, maintaining at the same time sufficient heat. It is exposed in this way for a certain number of weeks, when it is ready for the market. Great experience is necessary to carry on this process. This is the manner in which it is prepared in its own home. It is used there by the natives, a portion being grated off with a large file, and it is served in a glass full of cold water. Its effects are very refreshing, but its excessive use is deleterious. It contains two or three times the quantity of caffeine that coffee does, producing a happy effect on the nervous system, but if used in excess bringing on trembling and a palsied condition of the limbs.

* From a lecture at the Philadelphia College of Pharmacy.—*American Journal of Pharmacy.*

OILING THE SEA.

RESULTS of the scientific tests of Officer Meissel's new invention, an oil rocket designed to calm the raging of a troubled sea, appear to have been satisfactory enough to warrant the hope that shipwrecks will be rare occurrences ere many years. The principle here applied is as old, certainly, as the proverb which embodies it, but the method of application was novel. Four rockets, the same in appearance as those commonly used in ordinary pyrotechnical displays, but with the exploding cap removed and a light tin cylinder holding one pound of train oil substituted, were sent up at varying angles of projection, the result being that the sea was calmed for thousands of feet round about the spot above which they exploded and fell. The oil spread into a thin, silk-like sheet, which, extending rapidly, appeared to have the power of keeping the waves within peaceable limits. As these rockets can be carried with convenience and sent up without trouble, there is no reason, surely, why the enterprising steamship companies should not at once recognize their utility and add a number to the equipment of each steamer sufficient for the necessities of the average voyage. Officer Meissel's cylinder is a simple affair, and can be made to hold as much oil as may be desired. Through the center of the oil runs a small tube containing two ounces of gunpowder, which ignites as soon as the motive power of the rocket is spent, and, exploding, scatters the oil in a fine spray over the water. The action of the oil upon the water is almost instantaneous.—*Philadelphia Times.*

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